NORTH CAROLINA

DEPARTMENT OF ENVIRONMENTAL QUALITY

TECHNICAL GUIDANCE

for

RISK-BASED ENVIRONMENTAL REMEDIATION OF SITES

For all applicable sites according to

NC General Statutes 130A-310.68 through 310.77

Environmental Quality

March 2017

DEPARTMENT OF ENVIRONMENTAL QUALITY

TECHNICAL GUIDANCE FOR RISK-BASED ENVIRONMENTAL REMEDIATION OF SITES

Executive Summary

The Department of Environmental Quality is pleased to release this initial version of the Technical Guidance for Risk-Based Environmental Remediation of Sites. The provisions enacted in Session Law 2105-286 establish an expanded risk-based framework for making cleanup decisions at contaminated properties. This guidance is the culmination of significant work by members of the DEQ Remediation Team and it is intended to satisfy the mandates of the Session Law.

This guidance provides to the extent practicable, a common set of methods and standards for assessment and cleanup of contaminated sites. The risk-based approach described in this guidance hinges on the expectation that data density and the level of effort to assess a contaminated site can and should be a function of the complexity of a site's risks and its setting. The use of risk-based decision-making tools allows more freedom for setting and achieving cleanup levels, and at the same time increases the responsibility to thoroughly understand and assess potential receptors, exposure pathways, and risks posed by contaminants remaining in the environment. Selecting a risk-based remedy involves a balance between the level of certainty in understanding site conditions and the practicality of using land-use controls to manage risk where understanding of the site is limited. The ability to employ land-use controls to manage risks carries with it a responsibility to ensure that such controls are protective, achievable, sustainable, and consistent with surrounding land uses.

DEQ believes that the paradigm shift toward a risk-based approach to remediation presents an opportunity for state environmental cleanup programs to work collegially with remediating parties to develop remedial strategies that appropriately protect human health and the environment. Remediating parties are encouraged to communicate with their oversight program early in the process to discuss site conditions and ensure that the requirements are well understood.

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ASTM	American Society for Testing and Materials
CR	cancer risk
Csat	soil saturation limit
CSM	conceptual site model
DEQ	Department of Environmental Quality
DWM	Division of Waste Management
DWR	Division of Water Resources
EC	engineering control
EMC	environmental management commission
EU	exposure unit
GWSL	groundwater screening level
HI	hazard index
HQ	hazard quotient
HRE	health risk evaluation
IASLs	indoor air screening levels
IC	institutional control
IEUBK	Integrated Exposure Uptake Biokinetic
IMAC	interim maximum allowable concentration
LUR	land-use restrictions
Max	ceiling concentration
MCL	maximum contaminant concentration
NAPL	non-aqueous phase liquid
NCAC	North Carolina Administrative Code
NFA	no further action
NOIR	notice of intent to remediate
OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PEF	particulate emission factor
PSRG	preliminary soil remediation goals
PGPSRG	protection of groundwater preliminary soil remediation goals
POE	point of entry
QA	quality assurance
QC	quality control
PSRG	preliminary soil remediation goals
RAGS	Risk Assessment Guidance for Superfund
RAP	remedial action plan
RSL	regional screening levels
SESD	Science and Ecosystem Support Division
SGSL	soil gas screening level
SIM	Selected Ion Monitoring
SPLP	synthetic precipitation leaching procedure
SQL	sample quantitation limit
SSTL	site-specific target level
TCLP	toxicity characterization leaching procedure

TIC	tentatively identified compound
USEPA	United States Environmental Protection Agency
VF	volatilization factor
VI	vapor intrusion
VOC	volatile organic compound

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Administrative Procedures for Risk-Based Environmental Remediation of Sites
https://deq.nc.gov/permits-regulations/risk-based-remediation/forms

Contaminated Property: Issues and Liabilities Brochure
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_ContaminatedPropertiesPublication_20160718.pdf

DEQ Risk Calculator
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/DEQ%20Risk%20Calculator%2020161214.xlsm

Risk Assessment Report Forms
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/Risk%20Assessment%20Rpt%20Forms%2020161214.xlsm

Property Owner Consent
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Property%20Owner%20Consent%20form_20160722.pdf

Notice of Intent to Remediate
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Notice%20of%20Intent%20to%20Remediate_20160722.pdf

Fee Calculation Instructions
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Fee%20Calc%20Instructions_20160722.pdf

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https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/Remedial%20Investigation%20Report%20Contents%2020170123.pdf

DWM Vapor Intrusion Guidance
https://deq.nc.gov/about/divisions/waste-management/waste-management-permit-guidance/dwm-vapor-intrusion-guidance

Field Branches Quality System and Technical Procedures
http://www.epa.gov/region4/sesd/fbqstp/

Division of Water Resources (DWR) aquifer testing policy
https://ncdenr.s3.amazonaws.com/s3fs-public/Water%20Quality/Aquifer%20Protection/APS%20Policies/AquiferTestingPolicy-20070531.pdf

PSRG (Soil and Sediment Screening) Table
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/SF/IHS/guidance/SoilTable%20OCTOBER%202016%20-%20Finalr1.pdf

15A NCAC 02L Groundwater Standards and IMACs
https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/groundwater-standards

Federal MCLs
https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

15A NCAC 02B Surface Water Standards
https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/surface-water-standards

DWR Surface Water Classifications map
https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=6e125ad7628f494694e259c80dd64265

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General Risk Evaluation Process for Tiers 1 and 2
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/Risk%20Evaluation%20Process%20FlowChart%20020117.pdf

PSRG (Soil and Sediment Screening) Tables
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/SF/IHS/guidance/SoilTable%20OCTOBER%202016%20-%20Finalr1.pdf

15A NCAC 02L Groundwater Standards and IMACs
https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/groundwater-standards

Federal MCLs
https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

15A NCAC 02B Surface Water Standards
https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/surface-water-standards

DWM Vapor Intrusion Guidance
https://deq.nc.gov/about/divisions/waste-management/waste-management-permit-guidance/dwm-vapor-intrusion-guidance

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https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/Risk%20Evaluation%20Equations%20%26%20Calculations%2020170127.pdf

USEPA RSL Tables
https://www.epa.gov/risk/regional-screening-levels-rsls

DWR Surface Water Classifications map
https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=6e125ad7628f494694e259c80dd64265

National Listing of Fish Advisories General Fact Sheet 2011
https://www.epa.gov/fish-tech/national-listing-fish-advisories-general-fact-sheet-2011

DEQ Risk Calculator
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/DEQ%20Risk%20Calculator%2020161214.xlsm

Risk Assessment Report Forms
https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/risk_based_remediation/Risk%20Assessment%20Rpt%20Forms%2020161214.xlsm

EPA RSL website
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016

EPA RSL on-line calculator
https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search

EPA Superfund guidance for human health risk assessments
https://www.epa.gov/risk/superfund-risk-assessment-human-health-topics

Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children
https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#overview

Adult Lead Methodology Guidance
https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#recommend

EPA Lead Guidance
https://www.epa.gov/superfund/lead-superfund-sites

USEPA website (modeling)
http://www.epa.gov/land-research/models-tools-and-databases-land-and-waste-management-research

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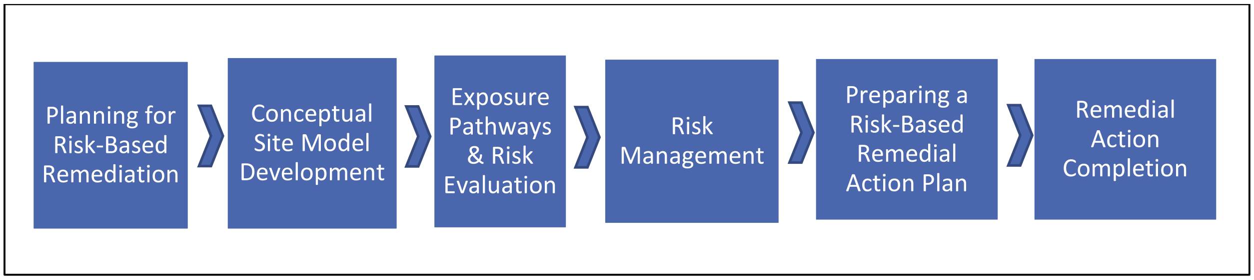
1. INTRODUCTION

This guidance document has been prepared to assist the public and state agency staff with the regulatory expectations associated with risk-based remediation of environmental contamination incidents under the oversight of the North Carolina Department of Environmental Quality (DEQ) Divisions of Waste Management (DWM) and Water Resources (DWR). This guidance is not intended to provide all the technical details of contaminated site assessment and remediation. Its purpose is to outline key elements and procedures specified in North Carolina General Statutes (G.S.) 130A 310.68 through 310.77 for implementing consistent and successful contaminant assessment and risk-based remediation strategies across applicable DEQ programs. Existing DEQ risk-based remediation programs (Brownfields, Underground Storage Tank, Dry-Cleaning Solvent Cleanup Act, and Pre-Regulatory Landfill) have additional guidance documents that provide the detailed technical requirements for specific types of chemical releases (petroleum vs hazardous substances) and permitting requirements related to the discharge that caused the contamination.

This guidance illustrates the type and format of information that should be presented to demonstrate that the remedy is appropriate for the site and protective of human health and ecological receptors. A methodology to evaluate risk is provided, as well as links to helpful tools, forms, worksheets and additional resources for preparing a risk-based remedial action plan (RAP). Figure 1-1 is a flow diagram of the main topics presented in this document.

Figure 1-1. Flow diagram of document topics.



The actions, criteria, procedures, and technical references contained herein are generally based on other related DEQ guidance documents, common standards of practice, and scientific study. Due to the wide range of conditions encountered at contamination sites, these guidelines cannot address every conceivable situation and every DEQ remediation program requirement. There may be situations where this guidance may not be sufficient or directly applicable. Please contact specific remediation program representatives for additional information or supplemental guidance.

1.1 Legislative Background

Risk-based remediation allows calculation of site-specific cleanup levels that are designed to protect public health and the environment based on the current and anticipated future use of a property. Whereas virtually all sites have had the option for risk-based soil cleanup and vapor mitigation levels, groundwater cleanup at most sites had to meet the 15A North Carolina Administrative Code (NCAC) 02L .0202 Groundwater Standards (15A NCAC 02L Standards). In North Carolina, risk-based remediation for all media has been available only under programs regulating leaking Underground Storage Tank sites, contaminated dry-cleaning sites, and pre-regulatory landfill sites. In 2011, G.S. 130A 310.68 through 310.77 allowed risk-based cleanups for industrial properties with releases reported prior to March 1, 2011 that were confined to the source property. To qualify for the risk-based cleanup option under these 2011 statutes, the site had to have manufactured a commercial product and the contamination had to remain on the source property.

Risk-based Remediation Programs (year established):

- Leaking Petroleum Underground Storage Tank Cleanup Program (1988)
- Dry-Cleaning Solvent Cleanup Program (1997)
- Pre-1983 Landfill Assessment and Remediation Program (2007)
- Hazardous Waste and RCRA Sites (2011 & 2015)
- Inactive Hazardous Sites (2011 & 2015)
- Petroleum releases from aboveground storage tanks and other sources (2015)
- Division of Water Resources Sites (2015)
- Permitted Solid Waste Sites (2015)

Programs with no risk-based alternative:

- Sites Regulated under the Coal Ash Management Act
- Permitted Animal Waste Management Systems

It should be noted that the term “site” in this document corresponds with locations of any known releases (or threatened releases) of hazardous substances. In some cases, the “site” may encompass multiple properties. Also, a property may have multiple sites due to multiple distinct releases. As a result, terms such as “on-site” and “off-site” can become confusing. To avoid confusion, this document also uses the term “Source Property” to refer to the property where the release occurred, and “Non-Source Property” to refer to any other properties overlying or potentially affected by the contaminant plume.

In 2015, House Bill 765 proposed amendments to many session laws, including G.S. 130A 310.68 through 310.77, that expanded the risk-based remediation option to include virtually all regulated sites, except those subject to remediation pursuant to the Coal Ash Management Act of 2014 and the requirements of animal waste management systems. As a result, remediating parties now have a choice to clean up their sites. They may pursue site cleanup to state standards or natural background levels that will allow any future use of the property, including residential use. No engineered or institutional controls requiring ongoing management are needed to achieve this “unrestricted-use” condition. Alternatively, remediating parties may pursue a risk-based approach to remediate to levels that are protective of human health and the environment, provided that affected property owners concur with the risk-based remedy and land-use restrictions (LURs). These “restricted-use,” risk-based levels consider site conditions and future use of the property and rely on maintenance of engineering and/or institutional controls to address risks to human health and the environment.

2. PLANNING FOR RISK-BASED ENVIRONMENTAL REMEDIATION

Risk-based remediation decisions rely on a thorough evaluation and understanding of contamination, the site, and the affected receptors. This involves development of a detailed conceptual site model (CSM), which is a description of site conditions and the ways in which receptors can be exposed to site contamination.

Links to risk-based remediation documents and forms:

G.S. 130A 310.68 through 77

"Administrative Procedures for Risk-Based Environmental Remediation of Sites"

"Contaminated Property: Issues and Liabilities" publication

DEQ Risk Calculator **and** Risk Assessment Report Forms

Property Owner Consent

Notice of Intent to Remediate

Fee Calculation Instructions

Risks posed by contaminants are a function of the current and intended future use of each affected property. Proposed future land uses, such as residential, industrial/commercial, or recreational should be consistent with surrounding land uses and local zoning requirements. In addition to future land use, a remediating party will need to consider several other factors when selecting a remedial alternative: regulatory requirements, risk management needs, cost and feasibility of implementing an engineered remedy versus pursuing a risk-based alternative for a fee, and property owner, public, and stakeholder input.

Remediation of a site is often an iterative approach that may require multiple strategies over time. An approved remedy may be monitored for some time. If site conditions improve or are better understood and predictable, a risk-based remedy may be proposed if risk to receptors can be managed through land- and groundwater-use restrictions. In general, any remedy needs to be appropriate for the type of contaminants and their behavior in the subsurface, hydrogeologic conditions, and risk to human and ecological receptors.

A risk-based remedy can be considered for a site when the site assessment is complete and documented in a remedial investigation report on file with DEQ. It is best to consult the Administrative Procedures before considering a risk-based remedy.

Remediators are encouraged to meet with their oversight program early in the process to discuss site conditions and ensure that the requirements are well understood.

2.1 Unrestricted-Use Versus Restricted-Use Remediation

Remediating parties have a choice for how a site is restored based on the property's intended use: unrestricted or restricted. Sites cleaned up to unrestricted use remediation standards have residual contaminant concentrations that are acceptable for residential use and uses where children are expected to frequent, such as schools and daycares. In some cases, it is not technically or economically feasible to reach the unrestricted-use cleanup levels, nor is it always possible to predict whether a particular cleanup approach will ultimately meet the unrestricted-use standards. Cleanup that relies on restricted land use allows remediating parties to take site-specific factors into account, and permits the use of institutional and engineering controls to achieve a protective remedy using cleanup levels that are not as stringent as the applicable unrestricted-use standards.

Analysis of the feasibility of implementing institutional controls should begin early in the remedial decision-making process since G.S. 130A-310.68 through 310.77 require that the responsible party obtain consent for alternate cleanup levels from all affected property owners and other persons that may possess property interests in the land.

A restricted-use, risk-based cleanup requires the agreement of all affected property owners in the placement of LURs on their property. Affected property includes all source properties and adjacent contaminated non-source properties, and currently uncontaminated properties where a contaminant plume could migrate if groundwater is used on that property. In addition, site remediation to restricted-use cleanup levels also requires administrative and oversight fees, ongoing maintenance of any engineered risk-management controls, and annual inspections of institutional and engineered risk management controls. In all restricted land-use cleanup scenarios, a LUR document and a survey plat will be attached to the property deed as part of the site remedy. The basic requirements of the two remediation alternatives are presented in Table 2-1.

Decision-making factors for selecting a remedy:

- Protection of public health and the environment
- Planned future land use
- Public and stakeholder perception and acceptance
- Costs
- Technical feasibility and effectiveness of remedy
- Time required to meet cleanup objective
- Implementability of institutional or engineering controls

Table 2-1. Requirements for unrestricted versus restricted property use.

Condition	Unrestricted Property Use	Restricted Property Use (Risk-Based Alternative)
Administrative fees required?	Program specific	Yes
Property owner permission needed for site-specific cleanup levels?	NA	Yes
Institutional *and/or engineered* controls needed?	NA	Yes
Ongoing annual maintenance/ inspection of institutional controls required?	NA	Yes
Soil and Sediment cleanup levels	Unrestricted Use Levels	Site Calculated Levels
Groundwater cleanup levels	NC 015A NCAC 02L Standards	Site Calculated Levels
Surface Water cleanup levels	NC 015A NCAC 02B Standards	NC 015A NCAC 02B Standards
Indoor Air Vapor	Residential Levels	Industrial or Residential Levels, as appropriate

2.2 Instructions, Forms and Fees

Before a plan is prepared for a risk-based cleanup under the provisions of G.S. 130A 310.68 through 310.77, the "*Administrative Procedures for Risk-Based Environmental Remediation of*

Sites" guidance should be reviewed and followed. These procedures have been prepared to provide remediating parties a clear set of administrative instructions, forms, and fee schedules to begin pursuing risk-based cleanup. The procedures discuss the following steps that should be completed in order to submit a risk-based RAP:

1. Confirm program eligibility
2. Complete the remedial investigation or site assessment
3. Provide information to and obtain written consent from all affected property owners
4. Prepare a Notice of Intent to Remediate
5. Calculate the required fees
6. Provide documents to DEQ
7. Pay the fee(s) and submit a RAP

The recent amendments to the risk-based cleanup statutes allows a remediating party to remediate a contaminated source property as well as any affected non-source properties to levels that prevent unacceptable risk. However, the following important requirements are in place to inform and protect the affected off-site property owners: provide affected property owners the DEQ brochure that informs them of the issues and liabilities associated with the contamination on their property, obtain written consent from affected property owners to use site-specific remediation levels that do not allow concentrations of contaminants on the off-site property to increase above the levels present on the date the written consent is obtained.

Restricted-use cleanup requires consent for site-specific cleanup levels from the following affected and potentially affected property owners:

- Source property
- All properties where a release has migrated, including publicly owned property (rights-of-way, roads, sidewalks)
- All properties where a release is predicted to migrate under natural conditions
- Non-source properties that are not predicted to become contaminated under natural conditions, but where a future water supply well could potentially draw the plume onto those properties

The DEQ brochure entitled "*Contaminated Property: Issues and Liabilities,*" provides current and future owners and users of contaminated properties with information about risk-based environmental cleanups, potential risks from residual contamination, and possible real estate issues regarding contaminated property. Remediators need to provide a copy of this brochure to all property owners affected by contamination that will be addressed by a risk-based cleanup remedy. Required forms and documents can be accessed at the links shown in the box.

2.2.1 Financial Assurance Requirements

In addition to the financial assurance required for permitted facilities (approximately 30 years), financial assurance is also required under the risk-based remediation provisions of G.S. 130A-310.68-310.310.77 to provide a means of ensuring that sufficient funds are available to implement and maintain the actions or controls proposed in a RAP.

The DEQ proposes to implement this provision in a manner that balances the need to ensure that funds are available to maintain critical remedial or engineering control measures with the need to reduce costly requirements that provide little to no benefit to protecting the public health or the environment. Based on experience drawn from DEQ regulatory programs with existing financial assurance requirements, DEQ intends to require financial assurance at sites pursuing risk-based remediation when:

1. The risk-based remedy includes long-term engineering controls, such as a landfill cap; and such controls require routine inspection and active maintenance to ensure that they provide adequate and reliable protection; or

2. The risk-based remedy relies on the long-term active functioning of a mechanical system, such as a groundwater treatment system, to remediate contaminated media and the associated monitoring and maintenance to ensure that the system is protective; or

3. The risk-based remedy relies on continuous, long-term functioning of a mitigation system, such as a vapor intrusion control system, to mitigate actual exposures and the associated monitoring and maintenance to ensure that the system is protective; or

4. Projected costs of maintaining the proposed risk-based remedial strategy is estimated to meet or exceed $500,000 over a 30-year period, with inflation adjustments included.

DEQ does not intend to require financial assurance for risk-based remedies where the only conditions of a no further action (NFA) determination involve low-cost activities, such as annual certification of land-use controls and inspection/upkeep of low-maintenance cover (e.g., parking lot, building footprint, or native soil with vegetative cover). Programs with significant financial assurance experience have found that long-term financial assurance for low-cost activities is unavailable and/or cost prohibitive, it may not always be possible to secure trusts and escrows for lower dollar activities, and corporate guarantees may not be available to all remediating parties. These inspection and upkeep activities would run with the land as part of the property restrictions, and subsequent property owners would typically be required to take on these duties. If a property owner failed to conduct required activities, the responsible party has the authority under law to enforce the compliance with the LURs, thereby preventing the reopening of the remedy.

2.2.2 Community Involvement

Community involvement is an integral part of all DEQ site cleanups. When the contaminant assessment is complete and enough information has been gathered to support a remedial alternative, a mailing list should be established by the remediating party to include, at a minimum, all owners of contaminated property, all owners of property to which the contamination is expected to migrate, all owners of land adjoining contaminated parcels, and jurisdictional local government contacts (health department, city manager, and others that may be required by the remediation program). Note that adjoining properties include owners of roadways bounding the property. Owners of property on the other side of the roadway are also considered to be adjoining landowners.

Since public notification is required at various stages in each cleanup program, remediators are encouraged to discuss the public involvement procedures with their oversight program early in the process to ensure that the requirements are well understood. Risk-based remediation according to G.S. 130A 310.68 through 310.7 requires that, a Notice of Intent to Remediate (NOIR) be issued by the remediating party to the mailing list as described in the "*Administrative Procedures for Risk-Based Environmental Remediation of Sites*" document. The NOIR must direct the recipient to the remedial investigation report in the DEQ files and include a statement of intent to clean up the site to site-specific remediation levels. This NOIR requirement is in addition to other public participation requirements of individual DEQ programs.

Once a proposed RAP is submitted to the appropriate remediation program, a public notice is prepared inviting interested parties to review and comment on the proposed RAP for the site. This notice includes the start and end dates of the comment period, instructions for reviewing documents online, and where to submit comments. The final RAP is not approved until all public comments are received and addressed in the proposed RAP.

3. SITE ASSESSMENT AND CONCEPTUAL SITE MODEL DEVELOPMENT

> This section provides a guide for the information that should be conveyed to DEQ regarding site conditions. DEQ recognizes that the remedial investigation and CSM may already be complete for some sites and documented in the files, while other sites may be in the initial stages.

As required in G.S. 130A-310.69, all site assessment activities and a final remedial investigation report must be completed and in the DEQ files to support the development, evaluation, and selection of appropriate response alternatives. The report should present sufficient data to characterize the site and to allow evaluation of the risks to human health and the environment. The report should present a conceptual site model (CSM) that characterizes the extent of contamination, depicts contaminant fate and transport, and evaluates the risk the contamination poses to identified receptors. A detailed CSM is critical for pursuing risk-based remediation since it not only presents the spatial nature of site contamination, but also the contaminant behavior over time. This spatial and temporal understanding of the site allows a level of predictability for understanding the fate of contaminants and threats to potential receptors in the future.

The level of detail of the CSM should match the complexity, setting, and levels of risk of the site. Development and refinement of the CSM as information is obtained throughout the remedial investigation will help identify investigative data gaps that may be critical for remedial decision making. A detailed and complete CSM is the basis for selecting an appropriate and effective remedy for a site.

The following sections focus on the elements of a CSM and describe the type of information that should be presented to demonstrate that a risk-based remedy is appropriate for the site. Some sites may already have a complete remedial investigation report on file that documents the CSM. Other sites may need a remedial investigation report completed and submitted to DEQ before a risk-based remedy can be pursued. The contents of a remedial investigation report should present the information described herein, including any additional information required by the specific DEQ remediation programs and the information required by G.S. 130A 310.69(a). Information existing in the remedial investigation report or other reports on file can be re-stated, summarized or referenced as part of a proposed risk-based remedial action plan.

3.1 Immediate Hazards

The need for immediate actions could arise at any time during the assessment and remediation phases of work. An imminent hazard or newly discovered condition may require immediate mitigation, remediation, or other action to abate a direct contaminant exposure to workers, nearby communities, and/or the environment. A remediating party may be required to notify their respective remediation oversight program of the discovery within 24 hours to review the data and determine whether conditions warrant immediate action. Interim remedial actions can address a threat in the short term while a long-term solution is developed. Examples of imminent hazards include, but are not limited to, the discovery of corroded drums or other industrial containers in a condition of imminent failure or any containers or wastes in close proximity to surface water in a storm drain, contaminated water supply wells, and indoor air contamination in occupied structures at levels that exceed levels established for the appropriate use of those structures.

3.1.1 Potable Water Supplies

All potable water supplies, including active and inactive water supply wells and springs, that could be affected by a nearby site should be sampled by the remediating party for all site contaminants and any daughter or breakdown products. Cases where permission to access a well or spring for sampling is denied should be well-documented and conveyed to the appropriate remediation program manager. If contamination is detected in a potable well or spring, the appropriate remediation program project manager should be contacted within 24 hours. A map showing the well location, the current use of the water, and the analytical results should be submitted along with, or immediately following, the notification.

If any contamination is detected, a health risk evaluation will be conducted by a DEQ or Department of Health and Human Services (DHHS) risk assessor to determine the appropriate use of the water supply. In cases where a contaminant concentration exceeds a drinking water limit, the affected supply users will be advised not to use the water for drinking or cooking. Supply users should be provided with potable water until the water is treated for suitable use or an alternate, permanent water supply is established. Drinking water limits to be used for this determination are:

1. First, the federal maximum contaminant levels (MCLs) adopted by the United States Environmental Protection Agency (EPA);

2. Second, if no federal MCL exists, the health based groundwater standards adopted in 15A NCAC 02L.0202 by the Environmental Management Commission (EMC) or the health based Interim Maximum Allowable Concentrations (IMACs) adopted by DEQ; and

3. Third, if no health based standard has been adopted by the EMC and no health based IMAC is available, concentrations calculated using procedures and references in 15A NCAC 02L.0202. Taste and odor thresholds will not be factors in calculating these concentrations, and standards adopted by the EMC based on taste and odor thresholds will be recalculated based on procedures and references in .0202 (d)(1), .0202(d)(2) and .0202(e).

If any contaminant exceeds the appropriate drinking water limit, the water will be further evaluated to determine if use should be restricted based on exposure via the dermal and inhalation routes. These "non-ingestive" uses may include, but are not limited to: showering, bathing, washing dishes, flushing toilets, and hand washing. Non-ingestive use limits shall be determined by combining the dermal and inhalation tapwater contaminant concentrations presented in the EPA Regional Screening Level (RSL) table.

3.1.2 Indoor Air

If volatile organic compounds (VOCs) are present in the subsurface and occupants of structures may be exposed to contaminants in indoor air, a vapor intrusion evaluation will be necessary. Vapor intrusion evaluation methodology and mitigation is described in detail in the DWM Vapor Intrusion Guidance. If the evaluation reveals that exposure to indoor air may adversely impact human health due to short-term or long-term exposures, immediately contact the appropriate remediation program manager to discuss whether immediate steps are necessary to eliminate or reduce the exposure concentration to less than the DWM action level. The response action time frame begins when the remediating party, their environmental consultant or DEQ receives the validated laboratory data.

Mitigation methods serve to eliminate the pathway between the source (contaminated groundwater and/or subsurface soils) and the receptors (building occupants), and can range from improving ventilation and sealing openings and cracks in the slab or foundation to installing an active soil vapor extraction system. When implementing mitigation measures, be sure to coordinate with the DEQ remediation program overseeing the site activities to ensure that any necessary approvals are obtained. Some remediation programs may have supplemental guidance to address the particular contaminants/releases addressed by the program.

3.2 Site Description and Characterization

A site assessment or remedial investigation should begin with desk-top research to gather information on the site history, contaminant release mechanism, surrounding land use, regional hydrogeology, and sensitive environments and receptors. Site data should be collected to identify local hydrogeologic conditions, the extent of contamination in all media, and the distance to receptors and data gaps.

3.2.1 Regional Setting and Surrounding Property Use

Land use of the site and surrounding properties can be described as undeveloped, residential, commercial, industrial, recreational, agricultural, open space, or other. Municipal water use and groundwater use in the vicinity should be documented. Any local government ordinances prohibiting water supply well installation or general groundwater use should be referenced.

A brief description of the regional geology and hydrogeology should include details on major aquifers, confining units, groundwater flow direction, surface water features, and any structural features such as faults, fracture systems, geologic intrusions, and subsurface geologic features that could serve as preferential groundwater flow paths. This information is meant to be general; however, if there are unique features in the project area, they should be documented.

3.2.2 Site History and Description of Release

An ownership chronology should be provided for the site property indicating the address, owner and/or lessee, the use or business, and a date range of the usage, if site use. Historical land use research should be traced to the earliest date of development. The following sources should be reviewed and documented. Unavailable items should be noted in the report.

- Aerial photographs to note any change in historic use, such as buildings, excavations, drum or container storage and/or disposal areas, and changes in land morphology, streams
- Fire insurance maps to identify past industrial and commercial land uses
- Property deeds to determine past owners, and possibly past land use
- Property tax files to obtain records of past ownership, appraisals, maps, sketches, photos, or other pertinent information
- Plat maps to show data about the historic location of landfills, ponds, and manufacturing and commercial activities
- Regulatory records review to document prior registration, closure, corrective action, engineering controls, institutional controls, covenants, and/or release notification information
- Interviews with current and former employees (e.g., managers, supervisors, foremen) and/or neighbors to gather information about past and/or present on-site hazardous material management practices
- Interviews with local officials from the fire department, health department and/or other emergency response agencies to inquire about spills or releases of hazardous substances in the project area

Discuss all hazardous waste management practices employed at the site property, including a list of types and amounts of waste generated, treatment and storage methods, and ultimate disposition of wastes. Also include a description of the facility's past and current permit status, if any, and a summary of the nature of all on-site contaminant releases, including one-time disposals or spills. The summary should include all contaminants released, the release mechanism/scenario, contamination source area(s), and volume released.

3.3 Site Assessment Procedures and Work Plans

The site assessment is generally conducted in at least two phases. The first phase should document the location of the release(s) of hazardous substances, characterize the chemical nature of such releases, and collect sufficient sampling data in order to compile a list of contaminants of concern. Subsequent phases of the investigation are used to delineate the lateral and vertical extent of contamination in all media and in each area of concern.

Work plans may be necessary for each phase of the assessment and should contain at least the following information.

- A description of the work planned, where the work is being conducted, and why.
- Proposed procedures to characterize site geologic and hydrogeologic conditions and to identify and delineate each contamination source as to each affected environmental medium. Include plans for special assessments, such as geophysical surveys or aquifer tests.
- Proposed methods, locations, depths, and justification for all sample collection points for all media sampled, including monitoring well locations and anticipated screened intervals.
- Proposed field and laboratory procedures for quality assurance/quality control.
- Proposed analytical parameters and analytical methods for all samples.
- A description of equipment and personnel decontamination procedures.
- A proposed schedule for site activities and reporting.

Minimum data requirements to support a risk-based remedy:

- Contaminant characteristics
- Contaminant delineation in all media
- Contaminant leachability
- Identified receptors and exposure pathways
- Aquifer properties and condition
- Statistically significant data sets for detailed analyses

Sample collection, preservation and container selection should follow the most current United States Environmental Protection Agency (USEPA) Region IV Science and Ecosystem Support Division (SESD) Field Branches Quality System and Technical Procedures.

The remediating party is responsible for developing appropriate health and safety measures that conform to all applicable federal and state regulations. The goal is to ensure that the health and safety of all persons in the vicinity, including the surrounding community, will not be adversely affected by any environmental activities.

3.3.1 Site Hydrogeology

Describe the soils and geology encountered at the site during drilling operations. Describe the site and area hydrogeology, including a discussion of depth to groundwater, groundwater flow direction, and hydraulic gradient. This information should be used to develop geologic cross sections of the site showing topography, lithology, water-bearing zones and confining layers. Discuss the effects of subsurface features including geologic and hydrogeochemical characteristics, underground utilities, fractured bedrock, and other preferential flow paths that may influence the migration of contaminants in groundwater and contaminated vapors in the vadose zone.

During the assessment phase of work, it is important to begin thinking about potential data needs for future remedial alternative considerations. For example, if engineered remedies and/or fate and transport models are being considered, then aquifer property data are essential, including bulk density, porosity, fraction of organic carbon, etc. Aquifer tests, such as pump test or slug test, should be planned to understand the aquifer's hydraulic conductivity and groundwater velocity. Refer to DWR's aquifer testing policy for additional guidance.

3.3.2 Sample Analyses for Establishing Site Contaminants

This section generally discusses the sample analysis procedures for sites where a list of contaminants has not yet been established from prior sampling and analysis. In most cases where a risk-based remedy is being considered, site contaminants may already be known from prior sampling, but breakdown products have not been recently evaluated. When analyzing environmental samples, remediators should ensure that any laboratory retained is currently certified to either analyze applicable parameters under Title 15A of the North Carolina Administrative Code, Subchapter 2H, Section .0800, or is a contract laboratory under the USEPA Contract Laboratory Program. Analytical data should meet the analytical method-specific quality control requirements and performance criteria. Sample and sample extract holding times, preservatives, containers and sample collection procedures should meet USEPA Region IV SESD Field Branches Quality System and Technical Procedures. All special procedures and quality control measures and results should be met and documented in the laboratory report.

Soil and Groundwater

There may be sites with no prior assessment history and where past practices at the site are uncertain due to poor recordkeeping of disposal practices and/or uncertainty of business practices. In these circumstances, soil and groundwater samples should be analyzed for a comprehensive list of constituents shown in the tables below. In addition, a library search (using the National Institute of Standards and Technology mass spectral library) of tentatively identified compounds (TICs) should be requested from the laboratory for any volatile and semi-volatile organic compound analyses. The library search should identify TICs for the largest 10 peaks in each analytical fraction that have reasonable agreement with reference spectra (i.e., relative intensities of major ions agree within ± 20%). The list of identified TICs should not include laboratory control sample compounds, surrogates, matrix spike compounds, internal standards, system monitoring compounds or target compounds. Sites where the contaminants have already been identified may not require all of the analyses specified. However, potential breakdown products of identified contaminants should be analyzed.

Table 3-1. Analyses to identify site contaminants.

Soil and Sediment Samples	
Volatile Organic Compounds[1]	SW-846 Method 8260 Target Compound List
1,4-Dioxane[2]	SW-846 Method 8260 Selected Ion Monitoring (SIM)
Semi-volatile Organic Compounds[1]	SW-846 Method 8270 Target Compound List
Metals[3,4]: antimony, arsenic, beryllium, cadmium, chromium (total), cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium and zinc	USEPA Method or method published in *Standard Methods for the Examination of Water and Wastewater* having the lowest detection limits, or having detection limits below unrestricted-use remediation goals. US EPA Method 1668 should be used for PCB congeners.
Pesticides, polychlorinated biphenyl (PCB) congeners, dioxins, cyanide, formaldehyde and any other analytes	

Hexavalent chromium if total chromium (1) (a) exceeds site-specific natural background concentrations or (b) is a suspected contaminant <u>and</u> (2) exceeds the remedial goal for hex. Cr	SW-846 Method 3060A[5] alkaline digestion coupled with USEPA method or method published in *Standard Methods for the Examination of Water and Wastewater* having the lowest detection limits, or having detection limits below unrestricted-use remediation goals.
Water Samples (including groundwater, surface water and soil leachate)	
Volatile Organic Compounds[1]	SW 846 Method 8260
1,4-Dioxane[2]	SW-846 Method 8260 SIM
Semi-volatile Organic Compounds[1]	SW-846 Method 8270
Metals[3,4,6] (see those listed for soil and sediment)	USEPA Method or method published in *Standard Methods for the Examination of Water and Wastewater* having the lowest detection limits, or having detection limits below the 15A NCAC 02L Standards. USEPA Method 1668 should be used for PCB congeners.
Pesticides, PCB congeners, dioxins, cyanide, formaldehyde and any other analytes	
Hexavalent chromium if total chromium (1) (a) exceeds site-specific natural background concentrations or (b) is a suspected contaminant and (2) exceeds the remedial goal for hex. Cr [7, 8]	USEPA Method 218.7 or Method 218.6 as modified by USEPA Region IV [8].

1 *Include the USEPA Target Compound List plus a library search of Tentatively Identified Compounds.*
2 *Include analysis for 1,4-dioxane if chlorinated solvents are present or if it is a suspected contaminant.*
3 *SW-846 Method 6010 does not have detection limits below the unrestricted-use 15A NCAC 02L Standards for all of the hazardous substance list metals. Therefore, it should not be used for first-phase metals scans.*
4 *If coal ash deposits are present, boron, iron and vanadium should be added to the metals scan.*
5 *Method 3060A extraction for soil and sediment samples allows for a 30-day holding time prior to extraction.*
6 *Rapid analysis of samples is recommended to lessen the contact time with the acid preservative. Filtration of groundwater and surface water samples before digestion is not acceptable. Highly turbid water samples for metals analysis should be collected using a low-flow purging and sampling technique, additional well development, and/or rapid analysis of samples to reduce contact time with the acid preservative.*
7 *Field filter samples for hexavalent chromium analysis within 15 minutes of sample collection, and collect each sample in a pre-preserved container separate from those for other metals analyses. See USEPA Region IV modified Method 218.6 for specific details.*
8 *Method 218.7 or Method 218.6 as modified by USEPA Region IV should be used. Method 218.7 requires low turbidity and allows for a 14-day holding time. USEPA Region IV has developed a modification of Method 218.6 that allows for a 28-day holding time. Use pre-preserved bottles as specified in the modification to the method. Laboratories should contact the USEPA in Region IV for methodology.*

Biological and/or physicochemical breakdown products should be analyzed during the assessment phase since this information may be important for evaluating the degree to which the contaminants naturally attenuate and determining whether they pose any unacceptable health or ecological risks.

If areas and constituents of concern have already been identified and confirmed at a site, then a request can be made to the DEQ remediation program manager to exclude irrelevant analyses.

Any contaminants present in soil, sediment, groundwater or surface water, along with the contaminant's daughter products, must be retained as contaminants of concern for further evaluation. Any TICs that have reasonable agreement with reference spectra, should be included in all subsequent analytical work unless the compound can be documented to be a laboratory contaminant, a naturally occurring compound, or otherwise an anthropogenic constituent. If only one sample is collected from an area of concern, include the library search of TICs in subsequent analyses. Check with the laboratory for possible procedures to quantify the TICs so that cleanup levels can be determined. A summary of the nature of any TICs eliminated from future analysis and reporting should be provided in the remedial investigation report, including reasons for discontinuing the constituent from future analysis.

Vapor

The potential for vapor intrusion (VI) should be evaluated at all sites with volatile contamination near or beneath a structure. The DWM Vapor Intrusion Guidance provides detailed procedures. A supplement to this guidance is also available which presents the step-wise procedures <add link> that may avoid unnecessary indoor-air sampling, since non-site related contaminants from paints, furniture, carpets, or cleaning agents can be found in indoor air.

Soil gas, crawlspace air or indoor air samples should only be tested for those contaminants detected in soil and groundwater along with all transformation (daughter) products using the TO-15 laboratory analysis. TO-15 SIM should be used if the TO-15 detection limits are less conservative than the appropriate screening levels presented in the DWM guidance for the chemicals of concern. The remediator should contact qualified laboratories prior to submitting samples to verify that the laboratory will be able to achieve detection limits at DWM screening levels/indoor air levels. Any contaminant in soil or groundwater, along with all contaminant daughter products, that are present in indoor air should be retained as a contaminant of concern for future vapor monitoring.

3.3.2.1 Analyzing for Polychlorinated biphenyls (PCBs) in Soil

Aroclors are varying mixtures of generally 50-100 of the 209 possible PCB related chemicals known as congeners. When released into the environment the congener profile of the original mixture is modified over time and with movement through each subsequent biotic or abiotic environmental medium, a process referred to as “weathering”. As a result, the analytical methods that report Aroclor mixtures do not adequately characterize weathered PCB-contaminated matrices. To adequately characterize PCB concentrations and potential human health and ecological hazards, USEPA Method 1668 should be used to analyze for all 209 congeners. Human health risks are evaluated as the individual concentrations of the 12 dioxin-like congeners (Table 3-2) and the risks associated with the remaining congeners are totaled as the “non-dioxin-like congeners”. Refer to Section 4.3.2 for additional information of human health risk calculations for PCBs.

Several samples should be collected in the more contaminated areas to identify the congener profile. Then, gross delineation for total PCBs may be conducted using USEPA Method 8082 since this method is typically less costly than Method 1668. Once the extent of total PCBs is known, the final delineation must be conducted using USEPA Method 1668 for all 209 PCB congeners. Due to limitations of Method 8082, however, it may not be used for final delineation.

Table 3-2. List of dioxin-like PCB congeners.

IUPAC No.	Dioxin-like PCB Congener
PCB-77	3,3’,4,4’-Tetrachlorobiphenyl
PCB-81	3,4,4’,5-Tetrachlorobiphenyl
PCB-105	2,3,3’4,4’-Pentachlorobiphenyl
PCB-114	2,3,4,4’,5-Pentachlorobiphenyl
PCB-118	2,3’,4,4’,5-Pentachlorobiphenyl
PCB-123	2’,3,4,4’,5-Pentachlorobiphenyl
PCB-126	3,3’,4,4’,5-Pentachlorobiphenyl
PCB-156	2,3,3’,4,4’,5-Hexachlorobiphenyl
PCB-157	2,3,3’,4,4’,5’-Hexachlorobiphenyl
PCB-167	2,3,4,4’,5,5’-Hexachlorobiphenyl
PCB-169	3,3’,4,4’,5,5’-Hexachlorobiphenyl
PCB-189	2,3,3’,4,4’,5,5’-Heptachlorobiphenyl

3.3.3 Field Data Quality Assurance/Quality Control

Duplicate samples, equipment rinsate blanks and trip blanks that accompany samples that potentially contain volatile compounds are strongly recommended to provide quality assurance (QA) and quality control (QC) of the field data collected. Program-specific guidance and professional judgment should be used to select and support appropriate QA/QC measures to be implemented. In some cases, additional support data may be needed for certain work phases, such as confirmation samples collected for site closure.

3.3.4 Method Detection Limits and Sample Quantitation Limits

The method detection limit (MDL) reported by the analytical laboratory represents the minimum concentration of a chemical detected by the instrumentation. MDLs are established using matrices with little or no interfering species and are considered the lowest possible reporting limit. The sample quantitation limit (SQL) is typically defined as the MDL adjusted to reflect sample specific actions, such as dilution or use of smaller aliquot sizes, and takes into account sample characteristics, sample preparation, and analytical adjustments. The practical quantitation limit (PQL) is often higher than the SQL and incorporates the laboratory operating conditions and is a report of the minimum concentration at which the laboratory can be expected to reliably measure a specific chemical contaminant during day-to-day analysis of different sample matrices.

Samples should be analyzed using approved methods that can attain SQLs or PQLs equal to or less than the DEQ screening levels for each contaminant, or the method with the lowest method detection limits. The laboratory should be advised of the desired limits ahead of time. The SQL is typically used for delineation, statistical analysis and risk evaluation, so the laboratory should provide written explanation for any analysis where the SQLs exceed 10 times the USEPA method detection limits. All constituents detected must be considered as site contaminants even if they were not definitively quantified. Any quality control concerns, data qualifiers or flags should be documented, evaluated and discussed. Data censored by elevated SQLs or PQLs should be noted and discussed. DEQ reserves the right to require consideration and further evaluation of censored chemicals when conducting a risk evaluation.

3.3.5 Evaluating Background Concentrations

Natural and anthropogenic background concentrations and upgradient sources can contribute to the site total contaminant concentrations. Because a remediating party is only responsible for contamination originating at the site, background concentrations should be distinguished from non-site related contamination.

Soil. Site-specific, natural background concentrations of metals should be established for sites with metals contamination. In some cases, regional background levels of dioxins, polynuclear aromatic hydrocarbons (PAHs) and/or PCBs may exist due to air fallout from industrial and non-industrial combustion sources and/or transformer/electrical grid discharges. Background samples for these contaminants should not be collected near identified source areas and should instead be collected from distances that reflect airborne deposition.

To withstand technical and regulatory scrutiny, natural background data should be collected within a geologic unit and soil type similar to that found in the contaminated area, from a comparable soil profile depth, hydraulically upgradient and outside the influence of site activities or other contaminant sources, and close to the site. Anthropogenic background data should represent a larger area and be collected outside source area and other contaminant source influences, and from locations on all sides of the site. After any obvious outliers are removed from the background data sets, the upper end of the range of concentrations can be used to establish background concentrations.

Groundwater. If contamination has migrated onto a property from upgradient sources, the remediating party needs to clearly demonstrate the relative contribution from the upgradient source and the source property. Published background ranges may be available in some regions for some naturally occurring metals. However, a more valid approach is to collect samples from wells in the vicinity of a site. In many cases, background concentrations in groundwater will be relatively easy to establish. However, determining background levels may be more difficult at larger, more complex sites, sites where background concentrations are higher than the 15A NCAC 02L Standards, or where the local geology contains the same naturally occurring inorganic constituents as the site.

At a minimum, background data should be collected from a hydraulically upgradient location in immediate proximity to the site and within the same groundwater horizon (depth/zone). The number of background wells and samples will be driven in part by the size, geologic complexity, hydrologic complexity of the site, the requirements of statistical methods, and/or other goals of the site assessment.

Surface Water and Sediment. If surface water assessment is necessary, background (upstream) surface water and sediment samples should be collected upstream of any on-site sources of contamination to establish natural or anthropogenic background concentrations. If contamination is found upstream of the site in concentrations greater than the downstream concentrations, downstream delineation may not be necessary. Confirm procedures with the appropriate remediation program manager in these situations.

3.3.6. Delineating the Extent of Contamination in all Media

> ***Delineate extent of contamination to background or unrestricted-use levels:***
> Soil, Sediment: PSRG Table
> Groundwater: 15A NCAC 02L Standards, IMACs, or Federal MCLs, whichever is lower
> Surface Water: 15A NCAC 02B Standards

In order to evaluate and properly manage risks, contamination in all media needs to be delineated in all directions to the unrestricted-use remedial goals or the appropriate background levels. Unrestricted-use remediation goals are provided as screening levels and can also be used as unrestricted-use cleanup levels. Screening levels are provided and discussed in Section 4.1. Since the screening level tables are updated periodically when new toxicological data become available from USEPA, it is important to check the DEQ website for the most recent version.

In addition to defining the lateral extent of contamination in soil, understanding the vertical extent of soil contamination is important for evaluating risks to human health and understanding the potential for soil contamination to leach to groundwater. In general, soil sample analysis for contaminants like metals, PAHs, dioxin, and pesticides should be collected in the top 3 or 4 inches, but most organics, especially volatile organics, should be collected at a depth of 9 to 12 inches for soils. The depths and extent of soil contamination must be known for the risk evaluation and to implement appropriate remedial actions, including engineered barriers and LURs. If unrestricted use of the property is desired, the entire soil column must meet unrestricted use levels. Confirm with your remediation program manager whether soil depth intervals require separate evaluation.

The lateral and vertical extent of groundwater contamination should be defined to determine distances to neighboring properties and potential receptors, including water supply wells, surface water bodies, existing and future occupied structures, and sensitive environments. The number and spatial extent of sampling points should be commensurate to the degree of certainty needed to make protective land-use decisions.

Hazardous substances with a density greater than water often results in and the need for a relatively complex assessment and remediation strategy. If the vertical extent of dense contaminants proves difficult to determine, contact the appropriate remediation program representative to discuss other lines of evidence that may be considered. Assessment methods that show decreasing concentrations with depth or that identify hydrogeologic features (e.g., confining beds, or discontinuous fractures) that limit flow paths may be options that an oversight program will consider in vertical delineation.

Where property access is not granted for lateral delineation of groundwater contamination, or ideal drilling locations are inaccessible due to physical constraints (wetlands, steep slopes, railroads, etc.), predictive computer modeling may be used if sufficient site data allow for reliable predictions. Computer models should be accompanied by all assessment and monitoring data. Documentation of accessibility issues, property access requests, and any other relevant information should also be presented. See Section 4 for additional guidance on fate and transport modeling.

3.4 Identifying Receptors

As the site assessment identifies and delineates the extent of environmental contamination, potential human and ecological receptors should be identified. Human receptors to consider include adult and child residents, non-residential workers, construction workers, recreators, and trespassers. Potential receptors will also be a function of the current and future land uses which may include residential, industrial/commercial, schools or childcare facilities, gardening or farming uses, or recreational uses.

Ecological receptors include any living organisms other than humans, the habitat which supports such organism, or natural resources which could be adversely affected by environmental contamination resulting from a release at or migration from a site. Contaminated surface waters and sediments can impact not only ecological habitats but also human health from recreational activities or ingestion of fish and shellfish.

Receptor surveys should be routinely reviewed and updated as needed to account for further delineation and migration of contamination, development of surrounding properties, and changes in land-use. If a threat is noted, immediate actions may be warranted to abate any imminent hazard to public health or the environment.

3.4.1. Receptor Scenarios

The DEQ identifies the following receptor scenarios where a person could come into contact with site contamination: residential, non-residential, construction worker, recreator, and trespasser. These scenarios typically consider ingestion and dermal contact with contaminated soil, and inhalation of vapors and particulates emanating from surface contamination. Occupants or potential occupants in existing or future buildings overlying or near subsurface contamination are potential receptors from vapor intrusion. The presence and location of the following receptors should be identified in relation to the site:

- Residential – Residential settings include single-family homes, townhouses, apartment buildings, and college/university dormitories. Receptors include both adults and children who are expected to spend a greater period of time in a residential setting than those individuals in a non-residential setting. These may include, but not be limited to, child/daycare facilities, schools through high school, and hospitals. Other property uses may be considered residential due to the exposure potential and the sensitive nature of the potentially exposed population.
- Non-residential – Non-residential settings include office buildings and commercial/ industrial facilities. Receptors in this setting consist of adults that work in such buildings or facilities. Colleges and universities (excluding dormitories) are considered non-residential use. Occupational settings that fall under the jurisdiction of the Occupational Safety and Health Administration (OSHA) may be handled differently than those not subject to OSHA regulations.
- Construction Worker – The construction worker scenario assumes that workers may be exposed to subsurface contamination during construction activities. The exposure

parameters associated with the construction worker scenario assume a shorter exposure time but higher contamination exposure as compared to the residential and non-residential worker scenarios.

- Recreator - The recreator exposure scenario refers to people who spend a limited amount of time at the site while playing, fishing, hunting, hiking, or engaging in other outdoor activities for pleasure. Since all sites do not provide the same opportunities, recreational scenarios must be developed on a site-specific basis.
- Trespasser – The trespasser scenario is highly dependent upon the individual site characteristics, the surrounding area demographics, and the level of security. Current exposures are likely to be higher at inactive sites than at active sites because there is generally little supervision of abandoned facilities. At most active sites, security patrols and normal maintenance of barriers, such as fences, serve to limit or prevent trespassing. USEPA Region 4 considers the "typical trespasser" to be an adolescent aged 7-16 (10-year exposure duration) with a body weight of 45 kilograms (kg). Frequency and duration of exposure parameters should be site-specific. Other trespasser populations may also be appropriate for a site. Consult a DEQ risk assessor early in the risk evaluation process if a trespasser scenario is needed.

3.4.2 Potable Water Supplies

All sources of potable water, including surface water intakes and private, community and irrigation wells, should be identified within one-half mile radius of each source area. If the source area is unknown, identify sources of water within a one-half mile radius of each point where contamination has been identified at the site. Wells used for industrial process water should also be identified. Workers may be exposed to water from these sources, or the water may be used in the food or consumer product manufacturing process.

For permitted solid waste landfill sites, the well-survey radius should be from the edge of waste disposal area. If the site is greater than one hundred (100) acres in size, the inventory and map should cover a one-mile radius from the center of each source area. Potable water sources including active and inactive water supply wells, springs, and surface water intakes can be identified by an area survey and data search as follows:

- Visually inspect properties to identify evidence of water supply wells such as well houses and well heads
- Review city water and sewer use billing records for nearby properties. Properties that have no water use record should be considered to use water supply wells
- Review county environmental health departments for records of private water supply wells which may include drilling and construction logs, records of well samples collected by the county for bacteria analysis, plats with wells located for properties under design, and some septic tank permits have water supply well locations indicated
- Mail out surveys to surrounding properties inquiring about water-supply wells
- Review DWR maps of surface water intake locations
- Review United States Geological Survey or other local maps for identified springs

The potential receptors should be tabulated and keyed to their locations on the receptor map with the level of threat from site contamination noted. Well users that are also served by a municipal water supply should be noted.

3.4.3 Surface Waters - Identification and Classification

The location of all surface water bodies within a one-half mile radius of a site should be identified. The use of a water body, the stream type, and its classification must be determined in order to understand its potential use and to determine the appropriate 15A NCAC 02B Standard to ensure its protection. For more information, refer to surface water identification and certification methods currently being used by DWR.

Stream Type. There are three stream types: ephemeral, intermittent, and perennial that are defined and regulated as follows:

- Ephemeral streams only carry storm water in direct response to precipitation. They may have a well-defined channel and they typically lack the biological, hydrological, and physical characteristics commonly associated with intermittent or continuous conveyances of water. These features are typically not regulated by DWR or the U.S. Army Corps of Engineers.
- Intermittent streams have a well-defined channel that contains water for only part of the year (typically during winter and spring). The flow may be heavily supplemented by storm water. When dry, they typically lack the biological and hydrological characteristics commonly associated with continuous conveyances of water. These features are regulated by DWR and typically regulated by the U.S. Army Corps of Engineers.
- Perennial streams have a well-defined channel that contains water year round during a year with normal rainfall. Groundwater is the primary source of water, but they also carry storm water. They exhibit the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. These features are regulated by DWR and typically regulated by the U.S. Army Corps of Engineers.

Classification. DWR classifies all surface waters according to the best uses to be protected (for example swimming, fishing, drinking water supply) and applies an associated set of water quality standards to protect those uses. All waters must at least meet the standards for Class C (fishable / swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water (Water Supply Classes I through V). Surface water classification data are available online on the DWR Surface Water Classifications map. If you need further assistance in determining the classification of a waterbody, contact DWR.

Wetlands are defined as those areas that are inundated or saturated by surface or groundwater for a portion of the year and support a prevalence of vegetation typically adapted for life in saturated soil conditions. Since wetlands provide a habitat for numerous plants and animals, all wetlands that could be threatened by a site should be identified.

The U.S. Army Corps of Engineers determines the presence and location of wetlands that are jurisdictional under Section 404 of the Clean Water Act. In general, if a wetland exhibits all three of the following characteristics: hydrology, hydrophytes, and hydric soils, it is a jurisdictional wetland.

3.4.4 Environmentally Sensitive Areas

All properties that make up the site and all adjacent properties should be evaluated for the existence of any environmentally sensitive areas. The following agencies should be contacted to determine if any special sampling (such as aquatic toxicity testing or fish tissue testing) is necessary:

- State parks
- Areas important to maintenance of unique natural communities
- Sensitive areas identified under the national estuary program
- Designated State natural areas
- State seashore, lakeshore and river recreational areas
- Rare species (state and federal threatened and endangered)
- Sensitive aquatic habitat
- State wild and scenic rivers
- National seashore, lakeshore and river recreational areas
- National parks or monuments
- Federal designated scenic or wild rivers
- Designated and proposed federal wilderness and natural areas
- National preserves and forests
- Federal land designated for the protection of natural ecosystems
- State-designated areas for protection or maintenance of aquatic life
- State preserves and forests
- Terrestrial areas utilized for breeding by large or dense aggregations of animals
- National or State wildlife refuges
- Marine sanctuaries
- National and State historical sites
- Areas identified under coastal protection legislation
- Coastal barriers or units of a coastal barrier resources system
- Spawning areas critical for the maintenance of fish/shellfish species within river, lake or coastal tidal waters
- Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which such fish spend extended periods of time
- State lands designated for wildlife or game management
- Wetlands

The presence of sensitive environments in the vicinity of the site may warrant an ecological risk evaluation. Contact a DEQ risk assessor for guidance on how to proceed.

3.4.5 Other Points of Compliance

For DEQ-permitted facilities, compliance boundaries are set by applicable rules. Permits at active facilities provide conditions to minimize releases of contaminants and ensure unrestricted use standards are achieved at compliance boundaries. In cases where a release resulted in contaminated groundwater beyond the compliance boundary of a permitted site, permittees should contact their oversight agency to determine if risk-based remediation is a viable option.

Though not a true receptor by definition, property boundaries could be considered as points of compliance for groundwater because groundwater contaminant plumes that threaten or migrate onto a neighboring property will either (i) need to be remediated to the 15A NCAC 02L Standards at the property boundary, or (ii) need to have the consent from affected neighboring property owners to impose LURs. In these cases, there needs to be sufficient distance, or buffer, between the groundwater plume and the next adjacent property so groundwater contamination will not migrate beyond the next property boundary either under natural flow conditions or if a well is installed in the future.

3.5 Understanding Contaminant Fate and Transport

A release will typically migrate vertically from its point of origin through unsaturated soil to groundwater and then laterally with groundwater flow. Volatile contaminants can also accumulate in soil gas and migrate into structures. Subsurface contaminant movement depends on the chemical properties of the contaminants and the physical, chemical, and biological characteristics of the site. Identifying and understanding a contaminant's mobility and persistence is an important component of a CSM.

> **Mobility** is the potential for a contaminant to migrate from a source.
>
> **Persistence** is a measure of how long a contaminant will remain in the environment.

Understanding contaminant transport requires an evaluation of spatial and temporal variability of contaminant concentrations within and across each media of concern. Understanding contaminant mobility and persistence is particularly important for establishing groundwater monitoring networks, predicting future migration and extent of contamination, and identifying pathways that pose risks to human health and the environment. The factors that affect contaminant fate and transport generally fall into one of four categories:

- Contaminant solubility and mobility
- Nature of soil matrix and aquifer properties
- Migration of contaminant mass as it moves through the groundwater flow system
- Chemical and biological factors that may degrade or alter the parent compound and the resulting chemical artifacts

3.5.1 Soil to Groundwater Transport

Contaminants released to soil can move downward as free-phase liquids or migrate downward when rainwater infiltrates the unsaturated soil. When low-permeability soil units impede vertical migration, the contaminants can also spread laterally in the vadose zone. When the soil moisture content is low, pore water movement becomes limited and contamination dissolved in pore water and sorbed to soil can also remain in the vadose zone for long periods of time, serving as a long-term source of groundwater contamination. Contaminants can eventually migrate to the water table and contaminate groundwater as a non-aqueous phase liquid (NAPL) or dissolved in pore water, depending on the mass and volume released. The PSRG table provides the contaminant concentration in soil indicating the presence of NAPL, as the Soil Saturation Limit (Csat). NAPL can remain for extended periods of time and act as a continuous source of contamination to groundwater.

3.5.2 Contaminant Transport in Groundwater

A comprehensive and quantitative understanding of the processes controlling the fate and transport of subsurface contaminants is necessary to understand the threat to nearby receptors and to develop effective plans for cleanup. A monitoring well network should be designed to define and track the spatial extent of contamination. Monitoring data should be gathered over a sufficient time-frame to understand seasonal fluctuations, effects of active remediation (e.g., soil source removal, groundwater pump and treat or substrate injection, etc.), and whether natural attenuation is occurring.

3.5.2.1. Factors that Affect the Solubility/Mobility of a Contaminant in Groundwater

The concentration of a groundwater contaminant will generally decrease as it migrates due to dilution, adsorption to matrix materials, or physical/chemical degradation. The distance over which contaminant concentrations decrease to acceptable levels will depend on the chemical properties of the contaminant, the physical properties of the saturated zone, and the magnitude of the contamination.

Groundwater plumes resulting from petroleum-related releases have been extensively documented and shown to migrate and degrade within reasonably predictable parameters in most cases. Conversely, groundwater plumes of persistent, higher-density chemicals (e.g., tetrachloroethene) can both migrate to great depths and extend for long distances – sometimes more than a mile.

The following lines of evidence should be used to evaluate groundwater contaminant plume behavior:

- The type of contaminant and its concentration, toxicity, solubility, specific gravity and persistence.
- The presence of NAPL.
- The geochemical conditions in the subsurface (pH, redox, ionic strength, and others).
- The type of solid phase host surfaces available for contaminant retention and their amount and distribution.

These factors may be measured and understood through analysis of groundwater, leachate, surface water, soil and sediment analytical data.

3.5.2.2 Factors Affecting Groundwater Movement

Groundwater movement is controlled by the distribution of horizontal and vertical hydraulic gradients, hydraulic conductivities, and porosities across the site. Sufficient water level data should be collected to calculate horizontal and vertical gradients and groundwater flow velocities across the property. Consideration should be given to the following physical site characteristics that affect these properties, and thus affect groundwater behavior:

- Local geology
  - groundwater flow system framework
  - groundwater flow horizons and their orientation, thickness, and properties
  - confining units, if present
  - bedrock fractures and other preferential flow zones
  - lithology
  - geologic structures
  - geologic heterogeneities or anomalies
- Site features
  - Man-made utility conduits
  - Impervious cover
  - Surface water impoundments
- Geomorphology
  - Recharge and discharge environments
  - Tidal influences to coastal surface waters
- Pumping wells: past, current, future

These factors are important because they influence groundwater velocity, direction, and discharge location. They may be measured and understood by coring, geologic mapping, stream mapping, land use mapping, well installation, water level measurements, aquifer tests, and solid phase sampling.

3.5.2.3 Assessment of Groundwater Discharge to Surface Water

Surface water quality must be adequately assessed to determine compliance with surface water quality standards. In accordance with NCGS 130A-310.68 (b)(2), "The site-specific remediation standard for surface waters shall be the water quality standards adopted by the Commission" (15A NCAC 02B "Surface Water and Wetland Standards" [15A NCAC 02B Standards]). Consequently, all remedial measures, including risk-based remedies, need to be designed to ensure that surface water quality criteria are met, and the best uses of the surface waters are protected. For wetlands, both soil/sediment and standing water should be assessed. A "multiple lines of evidence" approach will help remediating parties assemble the appropriate information to demonstrate that proposed remedies are protective of the surface water quality standards.

As described in Section 3 of this guidance document, remediators need a thorough understanding of the fate and transport of contamination in all media including any points or zones of contaminant discharge to surface water. The conceptual site model should convey a thorough understanding of the contaminants of concern and their source; the chemical, geological, and hydraulic characteristics of the aquifer; and the extent, transport behavior, and stability of the contaminant plume to allow critical decision making regarding surface water protection.

If the lines of evidence comprising the conceptual site model suggest that contaminated groundwater has the potential to affect surface water or sediment, then the groundwater contaminant discharge zones and/or the surface water need to be sufficiently characterized as part of the conceptual site model. When such characterization becomes necessary, sampling of discharge zones or surface water and sediment should be of sufficient extent, frequency, and duration to determine based on multiple lines of evidence if surface water or sediment is contaminated.

Contaminants in the discharging plume have the potential to accumulate in the bottom sediment, the substrate, or the banks of a surface water body, by sorption, precipitation, accumulation in pore water, or biological activity. In such cases, the human health risks associated with sediment contamination are addressed in the same manner as risks from contaminated soil, whereas risks to ecological receptors will need to be characterized by other methodology. Contact your remediation program for further guidance.

<u>Data Collection</u>

Groundwater, pore water and sediment samples should be collected from locations spanning the full width of the area where a plume is known or predicted to discharge into a surface water body. In addition, surface water, pore water and sediment samples should be collected from a sufficient number of upstream, downstream or offshore locations to determine whether groundwater is contaminating the surface water and, if so, to understand any attenuation away from the seepage face. The number of samples should be statistically significant to support decisions regarding compliance with the surface water standards. Seasonal variability in base flow, discharge conditions and potential tidal influences need to be considered when developing a sampling plan.

With the exception of some metals standards, 15A NCAC 02B Standards define surface water quality criteria as the maximum contaminant concentration allowed in the water column. There are no explicit requirements regarding the duration or frequency of contaminant concentrations that exceed the 02B Standards to infer whether surface water quality has been violated. Thus, a site-specific evaluation of surface water quality is necessary. Contact DWR regarding compliance with these standards.

Since contaminant detections in surface water can be intermittent and inconsistent, consideration will be given to the concentration, frequency, magnitude and duration of sample detections in both groundwater and surface water. Site-specific lines of evidence to support this evaluation may include:

- Classification of the water body (designated use) and classification of downstream uses;
- Chemical classification (volatile, semi-volatile, metals, PAH's, etc.), and nature of the contaminant (mobility, chemistry, miscibility, persistence, toxicity);
- Local hydrogeology, distance from plume to edge of surface water, stream type and morphology, differences in hydraulic head, and tidal influence;
- Stability of the groundwater contaminant plume;

- Surface water flow characteristics, including volume or flux across a specific discharge area;
- Presence or evidence of seeps and/or contamination along the stream banks;
- Field measurements of temperature and electrical conductivity differences between groundwater and surface water;
- Background concentrations from naturally occurring and anthropogenic sources in both groundwater and from upstream or regional sources;
- Attribution considerations if there are other nearby, upstream sources of contamination.

Such characterization and understanding of current conditions at and near the discharge point cannot be used to fully support a protective remedy unless contaminated soil and ongoing or NAPL groundwater sources have been either removed, remediated, controlled, or demonstrated to be stable.

Compliance with Surface Water Standards

At sites where contamination has been delineated, the plume is stable or decreasing, contaminant sources have been addressed, and site-specific conditions have been evaluated, one of the following determinations may be appropriate:

- If the lines of evidence demonstrate that contamination does not and will not extend to any surface water feature, a surface water is considered protected.
- If the lines of evidence demonstrate that contamination does, or may extend to a surface water feature, but does not and will not exceed any applicable 15A NCAC 02B Standards, a surface water is considered protected. If a standard is not available in the 15A NCAC 02B table, contact DWR for the calculation of a provisional value.
- If the lines of evidence demonstrate that contamination has caused a detection in surface water in excess of any numeric aquatic life or human health standards, the responsible party will need to evaluate the site-specific circumstances of the groundwater discharge to surface waters to determine whether the discharge constitutes a violation of the applicable 15A NCAC 02B Standards. For hardness (pH- dependent) metals, both acute and chronic standards (shown in the15A NCAC 02B table) should be considered. An acute impact can occur where the groundwater plume is discharging into a surface water body at concentrations high enough to cause immediate harm to aquatic life. Chronic impacts are generally manifested as sub-lethal effects (such as reduced reproduction or growth) resulting from exposures to lower concentrations over a longer time. To help ensure that sufficient and appropriate sampling data are gathered, consult with your oversight program.

3.6 Evaluating Plume Stability

A risk-based groundwater remedy is most applicable to a groundwater contaminant plume that is stable or shrinking over time. A plume is considered to be “stable” when monitoring data representative of the entirety of the plume demonstrate that the plume is not expanding spatially and that, overall, concentrations of chemicals of concern are not increasing over time. A stable plume indicates that groundwater contamination is contained, there are no increased risks to known receptors, a remedy is effective and protective, and reduced monitoring may be appropriate.

Stability does not imply lack of change, but rather change and variability are within predictable and manageable limits over time frames of regulatory interest. Stability is not an all-or-nothing concept. Plumes may be stable in some areas or with respect to some constituents, or sufficiently stable relative to identified risks to receptors.

A sufficient history of monitoring data should identify and confirm any variability in plume concentrations and extent due to seasonal water table fluctuations, contaminant sources, remediation, and/or natural attenuation. A risk-based remedy must demonstrate either of the following according to G.S. 130A 310. 73A:

- No contamination will migrate beyond the source property at levels above unrestricted-use standards, or
- Contaminant concentrations on the non-source property shall not increase above the calculated site-specific remediation levels, and written consent for site-specific remediation levels is obtained from the non-source property owner.

Potential property use changes that could alter plume stability, such as increased infiltration due to site development activities or use of future water-supply wells on the source property or on a nearby non-source property, need to be considered when developing a remedial strategy. In order to effectively manage long-term risks, institutional controls should ensure that both current and potential future risks are managed.

3.6.1 Data Needs

A history of groundwater monitoring data is needed to understand a plume's behavior and stability. The number of spatial and temporal monitoring points is directly proportional to the certainty of understanding plume conditions. There should be a sufficient number of monitoring points to define the extent of contamination both horizontally and vertically, to understand contaminant trends with distance toward receptors, and to understand contaminant trends over time. The monitoring network design should be based on all available information concerning the processes and factors expected to control contaminant distribution. For example, original contaminant source distribution, site geology, and hydrology can influence spatial and temporal variability of plume shapes, which should govern the monitoring locations and frequency decisions.

A demonstration of plume stability should include:

- Sufficient spatial coverage of points to monitor plume behavior
- At least (8) site-wide sampling events over time to permit statistical evaluation
- Maps of plumes spatial extent over time
- Graphs of trends in individual wells over time
- Graph of concentration vs. distance over time
- Calculations of plume area, plume mass, plume center of mass, and/or mass flux analyses

Monitoring frequency should be established to account for any variability in plume concentrations and extent due to seasonal water table fluctuations, tidal influence, contributing contaminant sources, remediation, and/or natural attenuation.

3.6.2 Data Analysis

Assessing plume stability requires analyzing historic groundwater data from individual well locations by using one or more of the following methods.

- Graphical methods (i.e., qualitative evaluation)
  - Concentration vs. Time Plots, Concentration vs. Distance Plots, and Concentration Isopleths Maps
- Quantitative methods
  - Statistical methods include well by well trend analysis (i.e., Mann-Kendall, linear regression)
  - Plume-Based Methods (i.e., plume area, plume mass, plume center of mass, and mass flux analyses

3.6.2.1 Graphical or Qualitative Evaluation

An interpretation of plume stability is based on sound scientific concepts and professional judgment. Plume stability should be supported by tabulated historic data, contaminant concentration contour maps, concentration versus time graphs for selected monitoring wells and concentration versus distance graphs showing concentrations along the plume centerline at select time points. Displaying the data in visual form supports conclusions made regarding plume stability as shown in Table 3-3.

Table 3-3. Graphical methods to evaluate plume stability.

Graphical Method	Description	Probability of Significant Risk of Plume Expansion	
		High	Low
Concentration vs. Time Plots	Contaminant concentrations vs. time at each groundwater monitoring well can depict the plume's attenuation rate. Graphs should include groundwater level data, as groundwater fluctuations can affect concentrations.	Trends in most wells visually stable and/or increasing	Trends in all relevant wells visually decreasing
Concentration vs. Distance Plots	Contaminant concentrations vs. distance along the plume centerline can reveal the plume's maximum extent in one dimension. Overlaying several sampling events may reveal an advancing or retreating plume along its centerline.	Moderate or no visual decrease in concentration along the plume centerline and generally stable or increasing trends in plots over time.	Significant visual decrease in concentration along the plume centerline and general decreasing trends in plots over time.
Concentration Isopleth Maps	Isopleth maps can depict the spatial extent of the plume in two dimensions. Graphing several sampling events may reveal an expanding or shrinking plume.	Generally increasing plume size over time.	Discernable decrease in plume size and extent over time.

Graphical plume stability analysis by comparing isopleth maps over time can provide compelling visual evidence for natural attenuation. However, a comparison of plume size over time does not always provide a complete analysis. In the case of a plume that discharges to a surface water body, or a plume geometry that is persistent over time, the plume shape may not change but the overall plume average concentration and mass may be decreasing. The change in plume mass would not be necessarily reflected in the visual analysis of isopleth maps.

3.6.2.2 Quantitative Evaluation

In addition to qualitatively evaluating plume behavior with visual depictions of site data, quantitative analysis of changes in overall plume concentration and mass can provide a better understanding of the plume stability. A common approach for evaluating plume stability is the use of statistical analysis techniques for single-well data. However, meaningful statistical tests will require substantial monitoring timeframes (eight or more consecutive events) to acquire sufficient data. Determination of temporal trends at individual well locations using regression, Mann-Kendall, or Mann-Whitney methods are common approaches to provide the primary lines of evidence for assessing plume stability. However, chemical concentrations trends at individual monitoring wells may be variable, which is not conducive to statistical evaluation of plume trends as a whole. At a given site, some wells may exhibit decreasing trends while others exhibit indeterminate or even increasing trends.

Evaluating trends in the overall plume area, average concentration, and mass provides a more thorough understanding of the stability of the entire plume as opposed to isolated locations within the plume. Plume-Based Methods include plume area, plume mass, plume center of mass, and mass flux analyses. With advances in computing power and the increasing size of datasets, plume-wide trend estimates of center of mass, total dissolved mass, plume area, and mass distribution in a plume have been put forward as useful tools in determination of plume stability. Mass flux and mass discharge estimates do have limitations. Reliable mass flux and mass discharge estimates often require more detailed characterization of hydraulic conductivity and groundwater flow than is typically available at most sites. Collecting the data necessary will increase total project cost. The costs may be relatively low for estimates based on models or mathematical analyses of existing data, but they can be significant for so called high-resolution mapping (measuring fluxes at relatively close-spaced points along one or more transects, sampling at multiple depth intervals at each sampling point). The uncertainty involved in mass flux and mass discharge estimates can be significant, and it should be quantified where possible.

3.7 Documenting the Conceptual Site Model

> ***Conceptual Site Model should be supported by:***
> - Regional maps showing key hydrogeologic features and receptors
> - Potentiometric maps
> - Isoconcentration maps
> - Cross sections showing lithology and contaminant distribution
> - Tabulated historic data
> - Graphs showing contaminant concentrations over time and distance

A detailed and complete CSM benefits from use of multiple formats to portray available information. A good narrative description is best to describe the site, its history, the nature of sources, quantitative aspects of migration pathways, the identity of receptors as well as the circumstances under which exposure is anticipated, and the property's future use. Often the formats will be dictated by the complexity of the site or area of concern and the amount and type of available data. Maps should always be included in a CSM and, at a minimum, depict relative location of sources and extent of contamination in all media, groundwater flow direction, preferred flow pathways and discharge points, surface water features, and receptors. Vertical profiles of the subsurface should depict lithologic intervals, hydraulic gradients, and contaminant distribution. Historic data should be tabulated and graphed to allow evaluation of trends in groundwater flow and contaminant distribution. The CSM should be modified and updated as new information is a gathered through all phases of the site investigations.

4. EVALUATING HUMAN HEALTH RISK

Human-health risk assessment is a scientific process for predicting the likelihood of adverse health effects from exposure to contaminants. Guidance for ecological risk assessments will be provided at a later date. Consult with a DEQ risk assessor if a site may have ecological concerns. Evaluating the risk to human health at contaminated sites involves the identification and characterization of site contaminants, migration pathways, human receptors (see Section 2), and exposure pathways (see Section 4.2.1). Risk assessment is approached in a multi-step process that starts out making conservative assumptions and then progresses to more site-specific assumptions and evaluations. The DEQ uses a risk-based approach to define the level of cleanup required at virtually all contaminated sites and to identify allowable concentrations of residual contamination that are protective of human health and the environment.

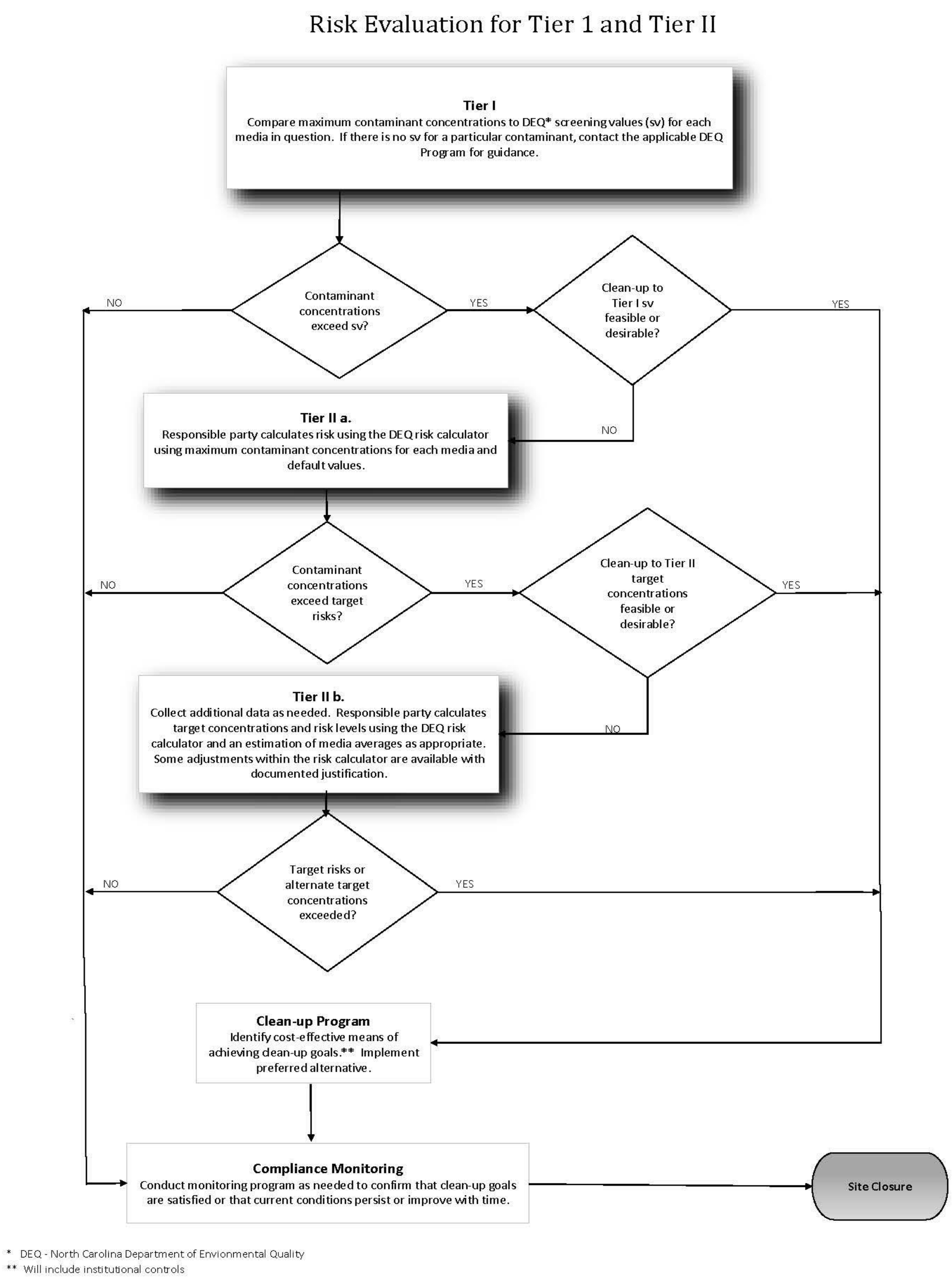
> Soil, sediment, and surface water must meet both the human health criteria and the ecological risk criteria (where applicable).
>
> **For protection of ecological receptors, contact DEQ.**

It should be noted that complex risk assessments will not always be necessary, especially for sites where contributing sources have been removed and site data indicate that the contamination is stable and predictable. In these cases, there may be manageable risks to receptors and, therefore, no further remediation required.

DEQ's human health risk assessment process is a three-tiered hierarchical process. Tier 1 screens each contaminant concentration against state-established preliminary remediation goals, also referred to as screening levels in this document. Tier 2 incorporates site-specific data, including aquifer properties, and evaluates the cumulative risk of multiple contaminants at a site. Tier 3 is a complex site-specific risk assessment requiring professional risk assessor oversight.

This tiered approach is fully consistent with the USEPA Risk Assessment Guidance for Superfund (RAGS).

Figure 4-1. General risk evaluation process for Tiers 1 and 2 ***(click on flowchart for pdf).***



4.1 Tier 1 - Screening Evaluation

Soil Screening Levels

15A NCAC 02L Standards

15A NCAC 02B Standards

Vapor Screening Levels

Use ***unrestricted-use screening levels*** for residential properties or property frequented by children. Residential values are also used as unrestricted-use values.

Use ***non-residential screening levels*** when the site will not be frequented by children. Sites that meet non-residential but exceed residential values will require additional controls, such as (but not limited to) LURs.

The first step in DEQ's human health risk assessment process is a screening evaluation in which individual contaminant concentrations determined to be unrelated to background conditions (see evaluation procedures in Section 3.3.5) are compared to conservative screening levels. DEQ has established unrestricted-use, health-based screening levels for soil, groundwater, surface water, and vapor intrusion (VI) to be used when the site use is expected to be residential or frequented by children (e.g., schools and day care centers). Unrestricted-use levels are the starting points for the DEQ risk screening process. A remediating party may choose to use the unrestricted-use screening levels as final cleanup levels to avoid restricted use of the property.

If a site fails the unrestricted-use screening, site contamination levels can be compared to the health-based, non-residential screening levels for restricted use if that is the intended land-use scenario. Restricted use screening levels are only applicable for non-residential, commercial, or industrial exposure settings that will not be frequented by children. If the site is currently or likely to become agricultural (crop, livestock, etc.), risks will also need to be calculated for this scenario due to the concern for possible uptake of contaminants by plants and livestock. Contact DEQ for additional guidance on this situation.

Generally, when contaminant concentrations fall below appropriate screening levels, no further action is necessary provided the site has been adequately characterized, all exposure pathways have been evaluated, and land use controls have been applied at sites exceeding unrestricted use standards. The equations and default exposure parameters used and discussed in the remainder of this section are compiled in the DEQ Risk Evaluation Equations and Calculations document.

4.1.1 Soil Screening Levels

The following DEQ soil screening levels are provided in the Preliminary Soil Remediation Goals (PSRG) Table:

- Unrestricted Use Health-Based PSRGs
- Industrial/Commercial Health-Based PSRGs
- Protection of Groundwater PSRGs (PGPSRGs)

4.1.1.1 Preliminary Human Health Soil Remediation Goals

The PSRGs are calculated using the chemical database, toxicity values, default exposure parameters, and equations found in the USEPA RSL tables. DEQ updates the PSRGs twice per

The term ***cancer risk*** will be used throughout this document to denote the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen.

A ***hazard quotient*** **(HQ)** is the ratio of the amount of a contaminant a person is exposed to vs. the amount that may cause non-cancer harmful effects. The ***hazard index*** **(HI)** is the sum of hazard quotients for a given scenario.

year following the release of USEPA's updates. The PSRGs are calculated for a cancer risk of 1.0E-06 and a non-cancer hazard quotient (HQ) of 0.20 per chemical. A HQ of 0.20 is appropriate for sites where no more than five (5) contaminants are present that act on the same target organ or through the same critical effect. The unrestricted-use PSRGs are calculated using a residential exposure scenario that includes both adult and child (1 to 6 years of age) exposures. Sites not frequented by children should first be screened against the unrestricted use PSRGs. If a contaminant exceeds the screening value, it may be screened against the industrial/commercial PSRGs, which assume a 40-hour workweek adult-only exposure scenario. Land-use controls restricting the property to industrial-use only would then need to be part of the site remedy.

Each contaminant is to be screened against the appropriate level presented in the PSRG Table. "J" flagged values (reported values identified by the laboratory as estimated concentrations) that exceed screening levels must be included in the risk calculations. If more than five contaminants with non-carcinogenic effects are detected at a site, a Tier 2 risk screen (see Section 4.2) should be conducted to determine if the cumulative risk of multiple chemicals is within acceptable limits. In addition, soil concentrations over specified areas and depth intervals may be averaged and compared with a screening level in some programs. These procedures are only available for sites with lesser contamination that may screen out at the Tier 1 level. Consult the appropriate remediation program manager for specific procedures on adjusting screening levels and averaging soil concentrations for Tier 1 screening. Average concentrations cannot be used for Tier 2 evaluations using the Risk Calculator.

4.1.1.2 Protection of Groundwater Preliminary Soil Remediation Goals

Soil screening levels are also provided to protect groundwater from contamination that could migrate vertically, or leach, from overlying contaminated soil. Protection of groundwater PSRGs are provided for unrestricted-use scenarios and are derived using the equation in Table 4-1. Leachability of unsaturated soil contamination can be further evaluated using site-specific information according to the methods described below.

Method 1: PGPSRGs are provided in the PSRG Table for most contaminants to protect all current and reasonably anticipated future uses of groundwater. Where a contaminant does not have a PGPSRG on the table, another method to understand leachability of contaminants from soils can be used as described below. Otherwise, contact the applicable remediation program. The tabulated values represent contaminant concentrations in any soil type that, if exceeded, may leach contaminants from soil to groundwater at concentrations above the established state cleanup standards. They are calculated using the USEPA soil leachate equation (see Table 4-1) with DEQ-selected default fate and transport parameters appropriate for North Carolina. The equation assumes the following:

- Infinite source (i.e., steady-state concentrations are maintained over the exposure period).
- Uniformly distributed contamination from the surface to the top of the aquifer.
- No contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) in soil.
- Instantaneous and linear equilibrium oil/water partitioning.
- Unconfined, unconsolidated aquifer with homogeneous and isotropic hydrologic properties.
- Receptor well at the downgradient edge of the source and screened within the plume.
- No contaminant attenuation in the aquifer.
- No NAPLs present.

The equation can be used to calculate the maximum allowed soil concentration that is protective of groundwater using the target groundwater cleanup level and site-specific soil parameters (e.g., organic carbon content, water-filled porosity, air-filled porosity, and dry bulk density). These geotechnical parameters should be measured by an analytical laboratory and substituted for the default values to calculate a site-specific leaching threshold. The complete set of equations used in this method can be found in the DEQ Risk Evaluation Equations and Calculations document.

Table 4-1. USEPA equation to calculate the protection of groundwater remediation goals (From the USEPA 1996 Soil Screening Guidance).

$$C_{soil} = C_{gw}\left[k_s + \frac{(\theta_w + \theta_a H')}{P_b}\right] df$$

	Parameters	Default Values	Units
C soil	Calculated Source Concentration for soil	not applicable	mg/kg - soil
Cgw	Applicable Groundwater Target Concentration: 15A NCAC 02L Standard	chemical-specific	mg/L - water
df	Dilution factor	20 (0.5 acre source size)[1]	unitless
Ks	Soil-water partition coefficient for organic constituents ks = koc x foc for inorganic constituents ks = kd	chemical-specific	L/kg
koc	Soil organic carbon-water partition coefficient	chemical-specific	L/kg
Foc	Fraction of organic carbon in subsurface vadose soils	0.001 (0.1%)[2]	kg/kg
Kd	Soil-water partition coefficient for inorganics	chemical-specific (pH=5.5)	L/kg
θw	Water-filled soil porosity-vadose soils	0.3[2]	Lwater/Lsoil

θa	Air-filled soil porosity-vadose soils	0.13^{2}	Lair/Lsoil
Pb	Dry bulk density	1.5^{2}	kg/L
H'	Henry's Law constant-dimensionless where: H' = Henry's Law constant (atm- m3/mole) x conversion factor of 41	chemical-specific	unitless

1. USEPA default value from 1996 Soil Screening Guidance
2. DEQ default value appropriate for North Carolina.

Method 2: Multiply the 15A NCAC 02L Standard in µg/L by 20 then divide by 1,000 to yield a target soil leaching concentration in mg/kg. While a conservative approach, this option may yield a less stringent leaching threshold concentration~~.~~

Target Leaching Concentration, mg/kg = (15A NCAC 02L Standard, µg/L) x 20 / 1000

Method 3: Determine the site soil's leachability by collecting several unsaturated soil samples from the source area (highest contaminant levels) and submitting them to the analytical laboratory for analysis using the Synthetic Precipitation Leaching Procedure (SPLP) or Toxicity Characterization Leaching Procedure (TCLP). TCLP is a procedure that uses organic acids to simulate typical landfill conditions. SPLP may be a more appropriate procedure because it is more representative of leaching under natural rainfall conditions. If contaminant concentrations in the source area soil leachate are below the respective groundwater remediation goals, then the leaching criterion will have been met for the site.

If contaminant concentrations in the source area soil leachate exceed the groundwater cleanup level (15A NCAC 02L Standards or the site-specific, risk-based cleanup level) then a leachability threshold soil concentration can be determined by collecting at least five (5) unsaturated soil samples from across the contaminated area (highest to lowest concentrations). Stratigraphic depth intervals of five (5) feet should be evaluated separately. Split soil samples must be analyzed for total contaminant concentration (in mg/kg) and SPLP (or TCLP) leachability (in µg/L). The data from multiple samples are then plotted as total soil concentration vs. leachate concentration to determine the linear correlation. The target protection of groundwater soil threshold concentration then becomes the value corresponding to a leachate concentration equivalent to the groundwater remediation goal for that contaminant determined using the linear regression equation and an appropriate safety factor. Use this threshold concept to guide soil removal and treatment options.

Note: If another laboratory model is proposed to determine leachability, its scientific validity must be demonstrated, and its precision and accuracy must be commensurate with its stated use.

Method 4: Cross-sections depicting the vertical extent of source area contamination, relative to the water table, along with groundwater samples collected beneath the source area, may be sufficient for evaluating whether contaminant transport via leaching is a concern. The following site-specific considerations may be used in combination to support that unsaturated soils are not contributing, nor have the potential to contribute, contamination to groundwater.

- The released volume of contamination is relatively small
- There is significant vertical separation between the base of soil contamination and the capillary fringe or water table
- A significant amount of time has passed since the release (minimum 20 years)
- Soil contaminants have never been detected in groundwater
- Groundwater concentrations in the source area have been naturally declining over time suggesting a depleted source

4.1.2 Groundwater Screening Levels

To determine if groundwater meets the unrestricted-use standard, maximum contaminant concentrations in groundwater are compared to the lower of the 15A NCAC 02L Standards, IMAC, and the USEPA Maximum Contaminant Level. For contaminants without 15A NCAC 02L Standards, the remediating party should contact DEQ.

If existing or proposed buildings are located within 100 feet of groundwater contamination, the maximum groundwater concentrations should be compared to the groundwater screening levels for VI to determine if additional assessment of the VI pathway is warranted. Screening for VI concerns is discussed in more detail in Section 4.1.5.

4.1.3 Surface Water Screening Levels

DEQ's risk-based environmental remediation provisions presented in G.S. 130A-310.65 through 310.77 state that surface waters at each site must meet the 15A NCAC 02B Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina. There is no risk-based cleanup option for surface water contaminated at levels that violate the 15A NCAC 02B Standards. The 15A NCAC 02B Standards are established by the Division of Water Resources (DWR) Classifications and Standards Unit. The 15A NCAC 02B Standards are established to protect human health and aquatic life based on the classification of use of the surface water body as established by DWR. Refer to the DWR's NC Surface Water Classifications map to determine a surface water body's classification.

The CSM should identify all surface water bodies within one-half mile of the site. On the 15A NCAC 02B standards table, find the water quality standard or criteria related to the designated use associated with the water body of interest (see footnotes in table). If a water body has multiple designated uses, the most protective (i.e., lowest) standard or criteria is to be applied. It is important to understand the surface water conditions upstream, at the site's potential or known discharge location, and downstream. Cleanup to less than upstream background concentrations is generally not required. If surface water contamination or contaminated groundwater discharge is causing sediments to exceed cleanup criteria, remediation of surface water and/or groundwater will be necessary to eliminate this effect. If a standard is not available in the 15A NCAC 02B table, contact DWR for the calculation of a provisional value.

4.1.3.1 Human Consumption of Aquatic Life

If bioaccumulative contaminants are released to a surface water body and the receiving surface water body can support edible aquatic life, a biota evaluation (fish, shellfish, crabs, etc.) may be needed. Common bioaccumulative chemicals include mercury, PCBs, chlordane, dioxins, and DDT (National Listing of Fish Advisories General Fact Sheet 2011). Refer to USEPA guidance to identify other bioaccumulative chemicals, which are generally identified as those with a log K_{ow} from ~3.5 to ~6.5 or greater. Investigations of bioaccumulative chemical exposures through the food chain will likely require the development of site-specific screening values and remediation levels, requiring a Tier 3 risk evaluation.

4.1.4 Sediment Screening Levels

Sediment can be contaminated through surface runoff and/or groundwater discharge. Maximum sediment concentrations are compared to the health-based soil PSRGs. This approach is overly conservative since sediment will be covered by water for most or all the year, limiting direct contact as a human health pathway. If sediment concentrations exceed the health-based PSRGs, proceed to the Tier 2 risk evaluation. If sediment becomes a risk driver, a site-specific exposure evaluation should be conducted. If sediment is contributing to surface water standard exceedances, remediation options should be evaluated.

4.1.5 Vapor Intrusion Screening Levels

At sites where volatile contaminants are present in the soil or groundwater within 100 feet (horizontally or vertically) of all current or future buildings, an evaluation of the current and potential impact to indoor air is necessary.

> Volatile contaminants are those where vapor pressure is greater than 1 mmHg or Henry's Law Constant is greater than 10^{-5} atm m^3/mol

DEQ has developed groundwater, soil gas and indoor air, screening levels for the residential and non-residential VI exposure scenarios. Exceedances of the screening levels indicate that VI poses a potential human health risk and further evaluation is necessary.

4.1.5.1 Indoor Air Screening Levels for Vapor Intrusion

Indoor air evaluation is usually the last step in the VI evaluation sequence. Because the groundwater and soil gas screening values are based on the Indoor Air Screening Levels for Vapor Intrusion (IASLs), an understanding of how the IASLs are derived is necessary prior to discussing the groundwater and soil gas screening levels. IASLs are developed for both residential and non-residential exposure scenarios and are calculated at cancer risks of 1.0E-06, 1.0E-05, and 1.0E-04 and a non-cancer HQ of 0.20. The lower of the selected (risk level) carcinogenic and the non-carcinogenic screening level is set as the IASL. The equations and assumptions used to calculate IASLs are located in the DEQ Risk Evaluation Equations and Calculations document (Equation A.9). IASLs units are in micrograms of contaminant per cubic meter of air (μg/m^3).

> It is essential that vapor intrusion evaluations proceed in a logical, step-wise fashion. Refer to the **DEQ VI Guidance and Screening Levels** when conducting a VI assessment.

Data reported in parts per billion volume or parts per million by volume (ppbv and ppmv, respectively) must be converted to μg/m^3 for risk screening as follows:

$$\frac{\mu g}{m^3} = \frac{(ppbv)(MW)}{24.45}$$

where: ppbv = parts per billion by volume
MW = molecular weight of the volatile contaminant (grams/mole)
24.45 = molar volume at 1 atm and 25 °C
1 ppmv = 1000 ppbv

4.1.5.2 Groundwater Screening Levels for Vapor Intrusion

The vapor intrusion groundwater screening levels have been calculated by dividing the corresponding target IASL at a cancer risk of 1.0E-05 and HQ = 0.20 by an attenuation factor (α) and then converting the vapor concentration to an equivalent groundwater concentration assuming equilibrium between the aqueous and vapor phases at the water table. The residential and non-residential groundwater to indoor air attenuation factor (α) is 0.001. Diffusion resistances across the capillary fringe are assumed to be accounted for in the value of α, and the equilibrium partitioning is assumed to obey Henry's Law (refer to DEQ Risk Evaluation Equations and Calculations document - Equation A.9.d).

4.1.5.3 Sub-Slab and Exterior Soil Gas Screening Levels for Vapor Intrusion

The soil gas screening levels (SGSLs) have been calculated by dividing the target IASL at a cancer risk of 1.0E-05 and HQ = 0.20 by an appropriate attenuation factor (α). The attenuation factor represents the factor by which subsurface vapor concentrations that migrate into indoor air spaces are reduced due to diffusion, advection, air exchange, and/or other attenuating mechanisms (refer to DEQ Risk Evaluation Equations and Calculations document - Equation A.9.c).

Many industrial and commercial buildings have heating, ventilation, and air conditioning systems that increase air exchange rates and are typically constructed with thicker, more competent slabs than residential settings. Increased air exchange rates result in a greater attenuation of contaminants in indoor air and thicker, more competent slabs may provide an additional barrier to VI. It is reasonable to assume a greater attenuation in non-residential settings, therefore, in general, DEQ uses a higher α (0.01) for non-residential SGSLs than for residential (0.03). An α of 0.03 may be used for certain non-residential exposure settings, such as commercial buildings with characteristics similar to those of residential buildings. This may include single family houses currently used for commercial purposes, or commercial buildings constructed with a basement or crawl space. Site-specific attenuation factors can be developed as part of a Tier 3 evaluation.

4.1.5.4 Screening Decisions

Vapor intrusion investigations should proceed in accordance with the DWM VI Guidance and any associated supplemental guidance. Screening generally begins with collecting and evaluating groundwater data for potential vapor intrusion risks, then collecting and evaluating soil gas or sub-slab gas for potential vapor intrusion risks, and finally proceeding to collecting and evaluating indoor air data. Exceedances of the screening levels indicate that VI poses a potential human health risk and that further evaluation is necessary.

- If the maximum groundwater contaminant concentrations exceed the vapor intrusion groundwater screening level, the appropriate next step is to evaluate sub-slab gas or soil gas to determine if vapor concentrations in the unsaturated zone indicate a potential risk to indoor air.

- If the maximum soil gas contaminant concentrations exceed the SGSLs, the next step is to conduct an indoor air evaluation.
- If the maximum measured indoor air concentrations exceed the IASLs, the next step will involve one or more of the following actions: indoor air confirmation sampling, VI mitigation, evaluation of potential indoor source(s), and/or site remediation.

Refer to the DEQ Vapor Intrusion Guidance and screening step by step guide for additional information.

4.2 Tier 2 - DEQ Risk Calculator

DEQ Risk Calculator and Risk Assessment Report Forms

The DEQ risk calculator uses the inputs and equations in the DEQ Risk Evaluation Equations and Calculations document to estimate risks to human health.

Where more than one contaminant exists at a site, cumulative risk is calculated by entering maximum concentrations of all detected contaminants into the DEQ Risk Calculator. **Potential site contaminants with laboratory reporting limits that exceed the Tier 1 screening levels should be included in the Tier 2 evaluation, unless lines of evidence can rule them out as contaminants.**

The DEQ risk calculator is an Excel-based, menu-driven program that can be used by the public to calculate risks to receptors from exposure to contaminated media through the ingestion, dermal, and inhalation routes, referred to as "combined pathways.". The calculator has multiple modules that quantify health risks for defined exposure scenarios. Inputs, equations, and procedures used in the risk calculator are consistent with those described in USEPA risk assessment guidance, including USEPA Risk Assessment Guidance for Superfund (USEPA, 1991 and USEPA, 2004), USEPA Soil Screening Guidance (USEPA, 1996 and USEPA, 2002), USEPA Region 4 Human Health Risk Assessment Supplemental Guidance (USEPA, 2014a), and the USEPA RSL website. Where USEPA default equations or inputs are not available, the DEQ has established North Carolina specific inputs exposure scenarios.

The DEQ risk calculator also has a simple, conservative contaminant migration estimator that incorporates a groundwater transport equation for dissolved contaminant plumes. This calculator is not appropriate for evaluating complex sites where conditions such as fractured rock, complex geology, NAPL or pumping wells exist. The contaminant migration worksheets in the risk calculator can be used to estimate soil to groundwater migration as well as groundwater to surface water migration of dissolved organic contaminants, provided that sufficient spatial data exists to define the plume's dimensions, and site-specific aquifer property data have been collected. Instructions on how to use the risk calculator are included as a tab within the calculator.

The risk calculator's chemical and toxicity database (chem-tox) values are obtained directly from USEPA's RSL Chemical-specific Parameters Supporting Table. The database will be updated as needed to reflect USEPA's latest information. The DWM "industrial/commercial" PSRG screening levels and the "non-residential worker" scenario in the risk calculator correspond to the

USEPA RSL "composite worker" exposure scenario. The construction worker equations in the risk calculator use sub-chronic (short term) toxicity data while the remaining receptor equations use chronic (longer term) toxicity data.

4.2.1 Exposure Pathways

Prior to using the DEQ risk calculator, the current and potential future exposure pathways will need to be identified. An exposure pathway is complete when all of the following are true: (i) there is a contaminant source, (ii) contamination is transported through a medium, (iii) contamination reaches a point where people may come in contact with it, (iv) there is a possible route of human exposure (ingestion, dermal contact, or inhalation), and (v) there are potential exposed populations. If any part of an exposure pathway is absent and will remain so, the pathway is said to be incomplete and no exposure is present. If an exposure pathway may be complete, is complete, or is predicted to become complete in the future, then the risks posed need to be evaluated. When there is not sufficient evidence to eliminate an exposure pathway, it should be carried through the risk evaluation process.

Common receptor scenarios are described in Section 3.4.1, and the associated exposure pathways used by the DEQ risk calculator are included in Table 4-2, below.

4.2.2 Exposure Units

The quantity and nature of complete current and potential future exposure pathways identified at a contaminated site will vary widely depending on contaminant distribution, surrounding land uses, and the proximity and type of receptors. Based on the complexity of a site, it will often be advantageous to segregate areas of the site into exposure units (EUs). Defining EUs is especially useful when there are multiple risk pathways to evaluate as it helps users take a methodical approach to a site-wide risk evaluation. An EU is a defined area of a site represented by a specific set of land use(s), receptors, contaminant concentrations, and exposure pathways. The boundaries of an EU are typically physical, surveyable boundaries, such as a property boundary, building footprint, fenced area, or room(s) within a building. Each potential pathway within each EU should be evaluated for risk using only the data that represents conditions that exist within the EU for the current and reasonably anticipated future receptors within that EU. The compilation of EUs used to conceptualize the exposure pathways is referred to as the exposure model.

Exposure units help determine which types of land-use controls are necessary for specific areas of a contaminated site. In a simple hypothetical example, an exposure model for a contaminated site may consist of three EUs: EU #1 represents an area on the source property where residual soil contamination is located under a building footprint, EU #2 represents an area on the source property where groundwater poses a potential future vapor intrusion concern, and EU #3 represents property(ies) with off-site groundwater contaminated at low levels above acceptable drinking water standards posing a potential future risk if groundwater is used for drinking. If such a site satisfies all the requirements necessary for a risk-based closure, it may be acceptable to manage potential future risks through land-use controls that include:

- EU #1 – vapor intrusion control measures for new development, cap maintenance measures to eliminate exposure to contaminated soil, and a restriction for groundwater use;

- EU #2 – vapor intrusion control measures for new development, and a restriction for groundwater use, and;
- EU #3 – control measures for future groundwater use.

Ideally, an exposure model and conceptual site model should be developed concurrently. Exposure models will vary widely depending on the conditions and complexities of a site. There may be several different exposure models that are sound and accurately represent the site conditions. Remediators are strongly encouraged to collaborate with qualified risk assessors and their oversight program when they plan to conduct a human health risk evaluation.

4.2.3 Inputs to Risk Calculator – Calculating Exposure Point Concentrations

To quantify exposure for each receptor, representative exposure point concentrations should be developed for each contaminant with a complete or potentially complete exposure pathway. The initial risk evaluation should be performed using maximum concentrations of each contaminant in each medium of concern in the EU being evaluated. If this initial risk evaluation indicates cumulative risks below acceptable levels, then no further evaluation is necessary. If the initial risk evaluation indicates cumulative risks above acceptable levels, further evaluation may be appropriate by using more appropriate exposure point concentrations, exposure assumptions, or by gathering additional data. Exposure point concentrations must be well documented, technically sound, defensible, and protective of receptors.

The following contaminant data should be entered into the risk calculator (for each EU, use the maximum concentration of each contaminant in each medium):

- Detected concentrations of all contaminants at the site, including those that do not exceed a screening level.
- Estimated ("J" flagged) concentrations for site contaminants.
- The SQL or PQL for contaminants where quantitation limits exceed screening levels and are elevated due to dilution.

If a specific contaminant is not in the calculator, consult with the oversight program.

> DEQ reserves the right to require consideration and further evaluation of censored chemicals when conducting a risk evaluation (see Section 3.3.4).

DEQ recommends that remediators consult with the oversight program in cases where initial iterative use of the risk calculator indicates that either the inclusion or omission of censored data results in significant changes in the calculated risk for an EU. Discussion of such evaluations needs to be included in the risk assessment documentation submitted to DEQ.

Some properties may have two distinct releases that pose differing levels and/or types of risk. Further, multiple releases on a property may be handled by more than one DEQ remediation program. In either of these cases, if contamination from multiple sources is comingled, the risk assessment should initially consider the risks associated with all contaminants where the contamination is comingled. If the risk evaluation of the comingled contaminants indicates cumulative risks above acceptable levels, then separate evaluations may be performed using only contaminants associated with each release.

These independent risk evaluations may identify which contaminant source is creating a higher risk, allowing for improved decision making regarding placement of LURs. The risk assessment report should clearly explain and document the all the decisions and data used to evaluate the risks posed by comingled contamination.

The most recent years of groundwater monitoring data are typically used in a risk evaluation, but there can be exceptions. In some situations, it may be acceptable to use only post-remediation monitoring data. If many years of groundwater monitoring data are available that show consistent and stable concentrations, it may be acceptable to include more than three years of data in the exposure point concentration calculations. In general, temporal averaging should be done conservatively and cover a time period over which the plume has been determined to be stable.

4.2.4 Risk Characterization for Cumulative Risk Pathways

The risk calculator contains modules that calculate non-cancer and cancer risks associated with individual contaminants, and cumulative risks by pathway for the receptor/scenarios listed in Table 4-2. Risk is calculated for each pathway within a given exposure scenario separately to identify the necessary LURs. As a result, the calculator will typically need to be run several times to account for multiple pathway and receptor scenarios at a given site. The risk totals from each pathway module are summed to calculate the cumulative cancer risk and non-cancer hazard index (HI) for each receptor for all combined pathways. The DEQ requires that cumulative risk for all contaminants in all media, for all routes of exposure (ingestion, dermal and inhalation), not exceed a cancer risk of 1.0E-04. For contaminants with non-cancer effects, the HI must be less than 1.0 for each target organ or critical effect.

Table 4-2. Contaminant exposure pathways in the DEQ Risk Calculator.

<table>
<tr><th colspan="2">PRIMARY PATHWAYS</th></tr>
<tr><th>Receptor Scenario</th><th>Pathway</th></tr>
<tr><td rowspan="2">Resident</td><td>Soil Combined Pathway</td></tr>
<tr><td>Groundwater Combined Pathway</td></tr>
<tr><td rowspan="2">Non-residential Worker</td><td>Soil Combined Pathway</td></tr>
<tr><td>Groundwater Combined Pathway</td></tr>
<tr><td>Construction Worker</td><td>Soil Combined Pathway</td></tr>
<tr><td rowspan="2">User Defined
(e.g., Recreator or Trespasser)</td><td>Soil Combined Pathway</td></tr>
<tr><td>Surface Water Combined Pathway</td></tr>
<tr><th colspan="2">VAPOR INTRUSION PATHWAYS</th></tr>
<tr><td rowspan="3">Resident</td><td>Groundwater to Indoor Air</td></tr>
<tr><td>Soil Gas to Indoor Air</td></tr>
<tr><td>Indoor Air</td></tr>
<tr><td rowspan="3">Non-residential Worker</td><td>Groundwater to Indoor Air</td></tr>
<tr><td>Soil Gas to Indoor Air</td></tr>
<tr><td>Indoor Air</td></tr>
<tr><td colspan="2">Combined refers to the possible routes of exposure and includes ingestion, dermal contact and inhalation.</td></tr>
</table>

The following sections provides additional details regarding risk characterization for each of these pathways.

4.2.4.1 Soil Combined Exposure Pathway

Each receptor/exposure pathway calculation contains pre-calculated screening levels (cancer risk, CR = 1.0E-06 and non-cancer HQ = 0.20 calculated from the current USEPA RSL toxicity values) for the applicable exposure routes. The calculator sums the route-specific risks for individual contaminants and determines the chemical-specific cumulative cancer risk and non-cancer HI using the "sum of ratios" approach as follows:

$$\text{Cumulative CR} = [(conc_x/SL_x)+(conc_y/SL_y)+(conc_z/SL_z)] \text{ x } 1.0\text{E-}06$$

$$\text{HI} = [(conc_x/SL_x)+(conc_y/SL_y)+(conc_z/SL_z)] \text{ x } 0.20$$

where: CR = Cancer Risk
x = ingestion, y = dermal, and z = inhalation
HI = Hazard Index
SL = Screening Level for cancer-effect (CR) or non-cancer effect (HI)

The risk calculator will quantify dermal risk for chemicals that have the potential for significant dermal absorption. This includes certain metals, SVOCs, PAHs, pentachlorophenol, and pesticides. The dermal absorption of VOCs is assumed to be insignificant.

Two equations are available to calculate the volatilization factor (VF), which is used to quantify risks from the inhalation of volatiles from outdoor sources: (i) unlimited source model for chronic exposure and (ii) mass limit model for chronic exposure. The risk calculator determines screening levels using both the standard VF equation and the mass limit VF equation. The lower screening level is then used for risk calculations. Further details on these models can be found in the Soil Screening Guidance (USEPA, 1996).

The particulate emissions factor (PEF) equation incorporates dispersion constants, which the USEPA RSL website provides for different geographic locations, including Raleigh, NC. The DEQ performed a sensitivity analysis to compare the results with dispersion constants from nearby locations (Charleston, SC and Atlanta, GA). The results indicated that the alternate location values did not substantially change the results of the calculations. Therefore, the risk calculator incorporates the default dispersion constants recommended by USEPA for Raleigh, NC to represent all regions of North Carolina.

The PEF calculations for a construction worker are more complex than for other receptors due to the increased potential for particulates generated from heavy vehicle traffic, grading, dozing, tilling, and excavation during construction activities. The DEQ performed an evaluation of PEFs generated using several methods. Refer to Part C of the DEQ Risk Evaluation Equations and Calculations document for the specific calculations and adopted value.

4.2.4.2 Groundwater Combined Exposure Pathway

Each groundwater risk module contains pre-calculated screening levels (CR = 1.0E-06 and HQ = 0.20 calculated from the current USEPA RSL toxicity values) for the applicable exposure routes when groundwater is used as tap water. The calculator sums the route-specific risks for individual contaminants and determines the chemical specific cumulative cancer risk and HI using the "sum of ratios" approach as follows:

$$\text{Cumulative CR} = [(conc_x/SL_x)+(conc_y/SL_y)+(conc_z/SL_z)] \text{ x } 1.0\text{E-}06$$

$$\text{HI} = [(conc_x/SL_x)+(conc_y/SL_y)+(conc_z/SL_z)] \text{ x } 0.20$$

where: CR = Cancer Risk
x = ingestion, y = dermal, and z = inhalation
HI = Hazard Index
SL = Screening Level for cancer-effect (CR) or non-cancer effect (HI)

The risk calculator will quantify dermal risk for chemicals that have the potential for significant dermal absorption. This includes certain metals, SVOCs, PAHs, pentachlorophenol, and pesticides. The dermal absorption of VOCs is assumed to be insignificant.

4.2.4.3 Surface Water Combined Exposure Pathway

Each surface water pathway calculation contains pre-calculated screening levels (CR = 1.0E-06 and HQ = 0.20 calculated from the current USEPA RSL toxicity values) for the applicable exposure route. Screening levels were derived from the USEPA RSL website and the RSL on-line calculator, and are based on a cancer risk of 1.0E-06 and an HQ of 0.20. The risks for individual contaminants are then summed to calculate the cumulative cancer risk and HI. The equations for this "sum of ratios" approach, which is consistent with USEPA guidance, are as follows:

$$\text{Cumulative CR} = [(conc_x/SL_x)+(conc_y/SL_y)] \text{ x } 1.0\text{E-}06$$

$$\text{HI} = [(conc_x/SL_x)+(conc_y/SL_y)+] \text{ x } 0.20$$

where: CR = Cancer Risk
x = ingestion, y = dermal
HI = Hazard Index
SL = Screening Level for cancer-effect (CR) or non-cancer effect (HI)

The risk calculator will quantify dermal risk for chemicals that have the potential for significant dermal absorption. This includes certain metals, SVOCs, PAHs, pentachlorophenol, and pesticides. The dermal absorption of VOCs is assumed to be insignificant.

4.2.4.4 Vapor Intrusion Indoor Inhalation Exposure Pathway

The DEQ Vapor Intrusion (VI) risk calculator consists of three different modules for residents and non-residential workers: 1) Groundwater to Indoor Air, 2) Soil Gas to Indoor Air, and 3) Indoor Air for a resident and non-residential worker. The VI calculators use risk characterization procedures in the latest version of the USEPA vapor intrusion screening level calculator. The attenuation factor for non-residential use is adjusted to NC-specific values.

Following the protocols in the DEQ VI Guidance, most VI evaluations start with screening of groundwater contaminant concentrations. If the predicted risk from indoor air exposure is above allowable limits, (cumulative cancer risk > 1.0E-04 or cumulative non-cancer HI > 1.0), then soil gas is sampled. Risks from exposure to estimated indoor air contaminant concentrations from the soil gas source air are calculated. If estimated indoor air risks are above allowable limits, indoor air is sampled and risks are calculated.

If calculated risks for groundwater to indoor air or soil gas to indoor air are within allowable cumulative risk limits, before concluding that VI poses no unacceptable risk, remediating parties should (i) ensure that their assumptions are sufficiently conservative to account for the variability in site conditions, and (ii) document the site conditions and assumptions used to estimate the indoor air risks.

When calculating indoor air inhalation risks from vapor intrusion, the DEQ VI risk calculator uses pre-calculated IASLs calculated from the current USEPA RSL toxicity values to quantify risks posed by contaminant exposure from either modeled (from groundwater or soil gas data) or measured indoor air concentrations as follows:

$$CR_a = (conc_a/SL_a) \times 1.0E\text{-}06$$

$$HQ_a = (conc_a/SL_a) \times 0.20$$

where:

CR = Cancer Risk
a = contaminant of concern
HQ =Non-cancer Hazard Quotient
SL = Screening level for indoor air using the equations and parameter values in the equations accessed using the DEQ Risk Evaluation Equations and Calculations document.
Conc = Concentration in indoor air. For groundwater and soil gas, indoor air values are estimated using the following equations.

To estimate indoor air contaminant concentrations from measured groundwater concentrations, the DEQ VI calculator uses the following equation:

$$IA\ (\mu g/m^3) = GW\ (\mu g/L)\ x\ H\ x\ \alpha\ x\ 1{,}000\ (L/m^3)$$

where:

IA = modeled contaminant concentration in indoor air
GW = measured groundwater concentration
H = Henry's Law Constant at 25°C (unitless) as
$[(mg/L\ \ vapor)\ /\ (mg/L\ H_2O)]$
α = attenuation factor of 0.001, ratio of indoor air concentration to source vapor concentration

The soil gas risk calculator applies to both sub-slab gas and exterior soil gas. To estimate indoor air contaminant concentrations from measured sub-slab gas and exterior soil gas concentrations, the DEQ VI calculator uses the following equation:

$$IA\ (\mu g/m^3) = SG\ (\mu g/m^3)\ x\ \alpha$$

where: IA = Contaminant concentration in indoor air
SG = soil gas concentration
α = attenuation factor (ratio of indoor air concentration to the source vapor concentration) = 0.03 for residential and 0.01 for non-residential exposure. If the non-residential attenuation factor is used, Institutional Controls to bar certain uses and/or require maintenance of mitigation systems are required.

The VI risks associated with the various media (groundwater, soil gas, and indoor air) can be calculated independently by the risk calculator. If soil gas or indoor air data are not available, groundwater data may be used for cumulative risk characterization and risk management decisions. Subsequent soil gas or indoor air data may be required to better quantify indoor air inhalation risks if the groundwater data indicates exceedances of the cumulative risk criteria.

4.2.5 Reporting Risk Assessment Results

When using the DEQ risk calculator, multiple iterations may be necessary to calculate risk for the various pathways associated with each EU. DEQ strongly encourages users of the risk calculator to review the Risk Assessment Report Forms to understand how to document the risk evaluation and to efficiently organize results from each iteration of the risk calculator. The risk assessment report forms organize the results by EU. For each EU, the user should describe the EU, explain the complete and incomplete exposure pathways, describe how exposure point concentrations were calculated, and summarize the calculated risks. The risk assessment report should also include figures showing the exposures units, contaminant distribution in each medium, receptors, land-uses, data tables, and other relevant supporting information. Discussion of the risk assessment results and any proposed remediation, engineering, and/or land-use controls should be included in the report. The forms function independently from the risk calculator but use the same nomenclature for consistency. Electronic submittal of the risk assessment using the report forms with the calculator is not required, but will facilitate timely review by DEQ.

4.3 Tier 3 - Site-Specific Risk Assessment

If risks calculated by the DEQ Tier 2 risk calculator for an EU result in a cumulative cancer risk greater than 1.0E-04 or cumulative non-cancer hazard index greater than 1.0, a more detailed (Tier 3) risk evaluation can be conducted by, or with oversight from, a professional risk assessor or toxicologist. For example, if the hazard index exceeds 1.0, a Tier 3 risk assessment may involve an evaluation of the target organ/critical effect-specific modes of action of the site's non-carcinogenic contaminants. Since contaminant toxicity values may be based on multiple target organs/critical effects, a more detailed toxicological evaluation of the specific effects of the site contaminants may conclude that a higher cleanup goal is protective.

Generally, Tier 3 focuses on the site-specific conditions, exposure parameter values and/or more sophisticated mathematical descriptions of fate and transport phenomena. At this level of complexity, site specific risk assessment models may need to be developed. It is anticipated that the vast majority of DEQ human health risk evaluations will be conducted using methodologies outlined for Tiers 1 and 2. While a Tier 3 evaluation may be used for any site, it is usually used on larger sites where the added cost of the risk assessment may result in a more cost effective cleanup strategy.

Guidance for conducting a Tier 3 risk assessment is detailed in USEPA Superfund Guidance For Human Health Risk Assessments and will not be reproduced here. Discussions with DEQ risk assessors prior to initiating a Tier 3 site-specific risk assessment are essential to appropriately scope out the process. Submittals describing current and future site uses, operable units, sampling strategies to fill any data gaps, exposure parameters and models, toxicity values, and processes for the selection of cleanup levels should be approved by DEQ prior to starting a Tier 3 evaluation.

4.3.1 Lead

Currently there is no EPA reference dose or cancer potency factor to quantify risks associated with exposures to lead. Exposure risks to lead are characterized based on predicted blood lead levels. The USEPA's residential health-based screening level for lead in soil is 400 milligrams per kilogram (mg/kg) and the USEPA's Maximum Contaminant Level (MCL) for lead in drinking water is 15 micrograms per liter (µg/L). If either of these levels is exceeded, the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children and the Adult Lead Methodology (ALM) may be used as appropriate to assess the site-specific risks and calculate remedial levels. The USEPA has also developed the ALM for evaluating the potential risks from lead in pregnant females. Refer to the USEPA lead guidance for additional information.

4.3.2 Polychlorinated biphenyls (PCBs)

1. Determine which PCB congeners are present at the site using USEPA Method 1668. See earlier discussion on PCB analyses in Section 3.
2. Risks associated with the 12 dioxin-like congeners (Table 3-2) are assessed individually. Risks for the remaining 197 congeners are evaluated as the sum of the non-dioxin-like congeners.
3. Calculate the concentration of the total non-dioxin-like PCB congeners.
   ∑total PCBs = ∑total dioxin-like congeners + ∑total non-dioxin-like congeners
   ∑total non-dioxin-like congeners = ∑total PCBs - ∑total dioxin-like congeners
4. Enter the concentrations for the 12 dioxin-like PCB congeners into the risk calculator and enter the total non-dioxin-like congeners concentration into the risk calculator as "Polychlorinated Biphenyls (high risk)".

4.4 Predicting Contaminant Transport

Current site conditions need to be well understood and future conditions predictable to account for new threats to receptors, such as surface water and indoor air. Further emphasizing the need for plume stability and predictability, a portion of G.S. 130A-310.73A(a)(2) states that "…site-specific remediation standards shall not allow concentrations of contaminants on the off-site property to increase above the levels present on the date the written consent is obtained."

Contaminant transport through the aquifer can be understood through hydraulic testing and evaluating water level and analytical data over time. A minimum of eight (8) monitoring events collected over at least two years is typically needed. Recharge areas, discharge points and preferential flow paths that may affect groundwater movement should be identified. Basing future predictions on the past behavior of the groundwater plume is often the simplest, most reliable method for ensuring future risks are addressed.

A fate and transport model can also be used to help predict a plume's extent or to demonstrate the efficacy of a groundwater discharge divide for a given aquifer. DEQ prefers that numerical models be used only in support of site monitoring data. The remediating party should first make use of conservative, simplistic models and calculations, like the DEQ Risk Calculator, before expending efforts on complex models that require more assumptions and result in less reliability. Models should not be used in lieu of site specific data to determine the extent of contamination or understand plume migration over time. The following section provides guidance on modeling groundwater transport.

4.4.1 Modeling Groundwater Transport

Models are useful for describing the behavior of a contaminant in groundwater, as long as they adequately reproduce measured observations of the groundwater system. It is important to choose models that are appropriate for the contaminant and conditions at the site. Most importantly, input parameters for the model should be consistent with the hydrogeologic setting defined during CSM development. Model inputs should be values that are representative of site conditions and derived from on-site measurements or analytical testing. Use of literature-based parameters or undocumented site-specific parameters is discouraged. Some modeling demonstrations may require site-specific calibration and/or field verification to be suitable for demonstrating confidence in contaminant plume behavior.

For this guidance, fate and transport focuses on defining the distribution, transport, and transformation of contamination at a given site. These processes include movement of contaminants by advection, dispersion, and diffusion; removal or release of contaminants by sorption or desorption from soils; and alteration of contaminants by biological processes, physical processes, or by chemical reactions. As such, a thorough hydrogeological investigation of the site is needed. The information gained from fate and transport studies is primarily used to evaluate exposure pathways, and to guide remediation decision making. To aid in this determination, the use of models may be warranted to simulate fate and transport processes of hazardous substances in and between various environmental media in order to visualize where contamination is located and where it will likely flow given a unique set of geological, hydrological, and biological conditions that exist at a site.

The following information is not intended to direct model application, as that should be performed by a user familiar with model operation, but rather provides general guidance for model selection, documentation, and verification.

4.4.1.1 Data Needs

Groundwater models cannot be used as a substitute for site-specific measurements of water quality and field data. Rather, the site-specific measurements should be used to constrain the modeling by providing data for model calibration, measurements of hydrostratigraphic unit geometries and properties, as well as sources and sinks to be modeled. A robust conceptual site model is critical in the modeling process. If the investigator incorrectly conceptualizes the hydrogeologic environment, then groundwater model results will be incorrect and will yield invalid predictions. The regional and site-specific hydrogeologic data in the conceptual site model is used to formulate a set of assumptions and concepts that can be evaluated quantitatively with the numeric or analytic models used for analysis and prediction.

Key aquifer parameters for the site are expected to be gathered or measured in the field, including bulk density, porosity, hydraulic conductivity, transmissivity. The spatial array of monitoring points used to measure these parameters should be sufficient, in the simplest cases, to understand the change in concentration in at least three points along the transect of the plume. More complex plumes or aquifers will require more monitoring points.

4.4.1.2 Model Selection

The user will need to decide whether it is more appropriate to use an analytical model versus numerical; deterministic or stochastic; steady state or transient; and also a one-, two- or three dimensional model. A model should be chosen based on its applicability to the site, availability of the required input data, and the defined purpose/objective of the modeling effort. It is important to choose a model that simulates the natural system as accurately as possible. Models should be 1) thoroughly documented in readily accessible published format, 2) peer-reviewed in the scientific literature (includes appropriate government publications from U.S.G.S. or USEPA), and appropriate to the site under investigation. Useful models can be found on the USEPA website. In all cases, site-specific data should be used in lieu of model assumptions whenever possible.

4.4.1.3 Model Documentation

Models applied at sites should be described in sufficient detail so that the model reviewer may determine the appropriateness of the model for the site, and confidence in predicted results of the model. Modeling documentation must detail the process by which the model was selected, developed, calibrated, and utilized. A model documentation report at a minimum must include the below information.

Introduction:

Provide a description of the problem(s) to be addressed and the purpose and goal of the model application.

Conceptual Site Model:

Provide a detailed description in text, tables, and figures, of the hydrogeology framework, hydrologic boundaries, hydraulic properties, hydraulic head distribution and hydraulic stresses of the modeled area. Processes for determining hydraulic properties should be described in detail.

Provide a detailed description in text, tables, and figures of the chemicals of concern at the site, types of impacted media, and known horizontal and vertical extent of the contaminants in the model area.

Provide a detailed description in text and tables of the fate and transport processes (e.g., dispersion, biodegradation) that impact contaminant concentrations and identify both impacted and potentially impacted receptors in the model area.

Computer Model:

Identify the type of model selected (e.g., analytical, numerical), model software (e.g., BIOCHLOR), its version number (e.g., Version 2.2), and describe its applicability and limitations as they relate to the problem to be simulated. The model should be capable of simulating the hydraulic, geochemical, and contaminant conditions at the facility.

Model Construction:

Provide a detailed description in text and tables of the fundamentals of the model (e.g., mathematical equations), boundary conditions (e.g., stream, receptor), and input parameters (e.g., hydraulic conductivity). Specify the processes by which all input parameters were generated (e.g., field measurement, literature value) or calculated (e.g., 95% upper confidence limit (UCL), average concentration).

Model Calibration and Sensitivity:

Describe in text, tables, and figures the degree to which the simulated model conditions match actual field conditions; the process by which input parameters were selected to achieve a match between the model's simulated conditions and actual field conditions; and model sensitivity analysis that varies input parameters to determine ranges of uncertainty in values of a specific parameter.

Predictive Simulations:

Provide a detailed description in text, tables, and figures of the flow and transport simulation outputs.

Summary and Conclusions:

Provide a detailed description in text, tables, and figures of the validity of the predictive simulation, model assumptions, model limitations, and recommendations for model refinement and/or performance monitoring.

<u>*Appendices:*</u>

Provide data and documentation used in support of the model that are not included in the text, tables, or figures of the report.

4.4.1.4 Model Verification

Models should be used as supplementary tools and not be a substitute for field investigations. Model simulation results and predictions are based solely on the type, quantity, and quality of the field data available to define the input parameters and boundary conditions during model development. Because major decisions may be based on modeling results, it is essential that modeling be conducted in a manner that provides confidence that the results of a model portray actual field conditions. For this reason, performance monitoring may be required as a means of determining the accuracy of the predictive modeling results.

4.5 Calculating Cleanup Levels

Site cleanup levels are target concentrations at which the site meets a level of risk that is protective and sustainable. Selecting cleanup levels is often a function of balancing costs, property use objectives, acceptance of land-use controls, community acceptance, and feasibility of meeting the cleanup goals. Establishing cleanup levels requires consideration of all contaminated media and how other media are affected by contaminants left in place. For example, in determining a cleanup goal for soil, one must evaluate how the selected cleanup level in soil will potentially affect groundwater, surface water, and indoor air, and what measures will be used to manage risks resulting from all contaminated media.

In some cases, cleanup levels can be selected from the PSRG tables and from promulgated standards. If a property owner's cleanup objective is to have no property use restrictions, the soil must meet the unrestricted use PSRGs (provided there are five or fewer contaminants with non-carcinogenic effects) and the ground water and surface water must meet applicable standards. The industrial-commercial PSRGs may be appropriate to use as final cleanup levels when land use-restrictions will limit site uses to industrial/commercial only <u>and</u> will impose any controls needed to ensure the protection of human health and the environment. In certain situations, such when there are five or fewer non-carcinogenic contaminants present, the PSRGs can be adjusted using simple equations as described in Section 4.5.1 below.

If site conditions are stable and a complete risk evaluation of site contamination concludes that current risks are acceptable and future risks can be managed with institutional controls (ICs), then remedial goals are considered to be met and no further cleanup is needed as long as the DEQ approved IC measures are recorded and maintained.

Where active remediation is necessary to address unacceptable risks, cleanup levels can be calculated using an iterative approach with the Risk Calculator or other acceptable methods. Remediating parties will be expected to demonstrate that the cleanup level calculations include appropriate input parameters, assumptions, and safety factors commensurate with the complexity of the site and level of uncertainty.

4.5.1 Adjusting and Averaging Health-Based Soil Cleanup Levels

The health-based soil remediation goals in the PSRG Table have been adapted from the USEPA Regional Screening Level Tables to account for cumulative risks associated with not more than five non-carcinogenic contaminants at a site that cause toxicity to the same target organ or critical effect. In consultation with the appropriate remediation program, the cleanup levels may be adjusted by using the USEPA RSL tables without using the Risk Calculator if there are no more than five non-carcinogenic contaminants present. These adjustments cannot be made to the Protection of Groundwater PSRGs, nor can they be calculated for sites with PCBs. The following procedures may be used, when appropriate, to adjust soil cleanup levels:

1. List the site contaminants present in soils that either exceed or are within one order of magnitude of a health-based remedial goal (i.e., 1/10th of the PSRG).
2. Sum the number of site contaminants that have carcinogenic health effects, non-carcinogenic health effects, or both as indicated in the USEPA RSL tables.
3. Calculate the adjusted remedial goal for each contaminant's health effect(s) using one of the three equations below.

Soil Contaminants with Only Carcinogenic Effects

The health-based remediation goals for carcinogens in the PSRG Table are calculated at a lifetime excess cancer risk of 1.0E-06. Since the maximum cumulative excess cancer risk for all contaminants and all pathways is a cancer risk of 1.0E-04, the health-based remediation goals for carcinogens ("C") may be adjusted to a cumulative cancer risk of 1.0E-04 using the equation below.

$$\text{Adjusted PSRG} = \frac{\text{PSRG x 100}}{\text{No. of “C” contaminants}}$$

If the adjusted PSRG exceeds the soil saturation concentration (Csat) provided in the PSRG Table, then the Csat value becomes the adjusted remedial goal.

Soil Contaminants with Only Non-Carcinogenic Effects

The health-based remediation goals for non-carcinogens shown in the PSRG Table are based on a hazard quotient of 0.20. The hazard quotient of 0.20 is used to account for multiple (average of five) non-carcinogens in the same target organ or critical effect group. For sites with five or less non-carcinogens ("N"), the remediation goals may be adjusted using the following calculation:

$$\text{Adjusted PSRG} = \frac{\text{PSRG x 5}}{\text{No. of “N” contaminants}}$$

If the adjusted PSRG exceeds the soil saturation concentration (Csat) provided in the PSRG Table, then the Csat value becomes the adjusted remedial goal.

If there are different target organs/critical effect groups, the remediation goals may be adjusted based on the number of non-carcinogens per target organ/critical effect group. A toxicologist should be consulted prior to making adjustments based on target organs/critical effect groups.

Soil Contaminants with Both Carcinogenic and Non-Carcinogenic Effects

If a contaminant that has both carcinogenic and non-carcinogenic effects, adjusted health-based remediation goals must be determined for each health effect and compared. **The final adjusted remediation goal will become the lower (more health protective) of the two concentrations**. Note that only the USEPA RSL tables are used for these calculations.

1. **To determine the carcinogenic value**:

$$\text{Adjusted PSRG} = \frac{\text{EPA Carcinogenic Screening Level x 100}}{\text{No. of “C” contaminants}}$$

2. **To determine the non-carcinogenic value**:

$$\text{Adjusted PSRG} = \frac{\text{EPA Non-carcinogenic Screening Level}}{\text{No. of “N” contaminants}}$$

3. The lower result of the two calculations then becomes the adjusted PSRG for that contaminant.

4. If the adjusted PSRG exceeds the Csat provided in the PSRG Table, then the Csat value becomes the adjusted remedial goal.

5. RISK MANAGEMENT / ENSURING PROTECTIVENESS OF REMEDY

Once the risks are quantified, procedures must be implemented to manage those risks in a way that ensures protection of human health and the environment. Risk-management decisions focus on the significance of the risk and how it should be addressed. To effectively manage risk, the following factors should be considered:

- Scientific factors: the level of risk determined from the risk evaluation and the cleanup levels needed to mitigate unacceptable risks
- Technical feasibility factors: feasibility of implementing a risk management option
- Economic factors: the cost of risk mitigation and the benefit of the outcome
- Social factors: land use, zoning, community input
- Political factors: interactions among branches of the Federal government, local government entities, special interest groups, or concerned citizens.

All proposed risk-based remedies must demonstrate that they are protective of existing and potential future receptors (e.g., water supply wells and occupied structures). LURs are imposed on currently affected properties, but consideration must be given to potential future conditions.

For example, any potential future use of groundwater on nearby non-source properties that could create an unacceptable risk must be restricted with property-owner permission. Even though the risk assessment will identify the risks associated with current conditions, the potential for contaminants to migrate to existing or future human and ecological receptors (or uncontaminated, adjacent properties) must also be considered, evaluated, and discussed.

5.1 Engineered Controls to Mitigate Risks

Engineering controls (ECs) are put in place to manage unacceptable risks and serve as a condition of a no-further-action determination. They are generally intended to be in place for long periods of time, if not permanently.

ECs encompass a variety of engineered and constructed physical barriers to contain and/or prevent exposure to contamination on a property. Many different types of ECs can be implemented, depending on the contaminants found and the type of media impacted. The following is a list of the more commonly used ECs. Individual DEQ remediation programs may have a preference or specifications for certain technologies, so coordination with the Department is highly encouraged.

- **Capping in Place (Asphalt or Concrete)** – The use of paved areas (e.g., parking lots, roadways) and building foundations as surface barriers or caps over contaminated soil. The result is a high strength, low permeability cover that reduces surface water infiltration and stabilizes contaminated soils. As a result, the cap prevents contact with the contaminated soil and may limit contaminant mobility protecting groundwater.
- **Capping in Place (Clean Fill)** – Placement of defined thickness of clean fill over an area of contaminated soil to prevent contact with the contaminated soil. The thickness is typically 18 inches, but may vary among remediation programs. A geotextile fabric marker is often required, and erosion control measures must be in place.
- **Passive Depressurization Systems** – Installation of a passive vapor control system in conjunction with a vapor barrier under buildings to minimize potential migration of volatile contamination to indoor air. A passive depressurization system relies on a natural convection of air to draw air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Active Depressurization Systems** – Installation of an active vapor control system in conjunction with a vapor barrier under buildings to minimize potential migration of volatile contamination to indoor air. An active depressurization system consists of a fan or blower which draws air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Groundwater Migration Barriers**– The use of groundwater flow, chemical or impermeable barriers to limit exposure by impeding or preventing migration of contaminated groundwater or leachate from a source area or site.

Although these five ECs are the most commonly used, other types of ECs are also used to reduce exposure to and migration of contamination left on the property:

- **Security Barriers and Fencing** – Used to restrict access to contaminated areas.
- **Solidification/Stabilization** – Occurs by injecting or mixing cement into contaminated soil to lock contaminants into a structurally sound mass of solid material for disposal.

- **Geotextile Fabric Barriers** – Separate, filter, drain, or reinforce soils.
- **Engineered Caps** – Designed to meet specific performance and containment requirements such as permeability.
- **Leachate Collection Systems** – Direct and collect contaminated leachate, and then transport it offsite for disposal.

In all cases, ECs must be inspected and maintained for integrity on a regular basis, and the results reported to DEQ in an annual inspection report. Land-use restrictions would be required to ensure the barriers are maintained and this duty would run with the land.

5.2 Institutional Controls

Institutional controls (ICs) are required for all cleanups that do not meet unrestricted-use standards. ICs are administrative or legal instruments (e.g., deed restrictions/notices, local ordinances, covenants, zoning) that impose restrictions on the use of contaminated property or resources to protect from current or potential future exposure to contamination. ICs also identify the presence of engineered controls and their long-term maintenance and monitoring requirements. For example, the most common ICs (e.g., deed notices and LUR document) provide notification that residual contamination remains on a property and identify engineered controls such as caps, mitigation barriers, or fencing, which are intended to restrict access and exposure to contamination and/or eliminate further migration of contamination.

In most DEQ remediation programs, two legal documents are recorded at the Register of Deeds Office in the County where the site is located: a LUR document and a contaminant notice survey plat (see Table 5-1). Although the content of the documents is similar, the title of the documents may differ among DEQ remediation programs. However, for all risk-based cleanups under G.S. 130A 310.68 through 310.77, the survey plat can be titled "Notice of Residual Contamination."

5.2.1 Reliance on State or Local Land-Use Controls

According to G.S. 130A-310.71(e), the Department may approve, in lieu of a recorded LUR document, other State or local land-use controls, provided they protect public health, safety, and welfare and the environment. However, even if state or local controls are in place and they are necessary to protect future use of the property, permission from all affected property owners must be obtained to record a Notice of Residual Contamination (survey plat) on the property's chain of title. Affected property owners include those that currently have contamination as well as those that could become affected in the future due to natural contaminant migration or use of existing or new water supply wells. At a minimum, the following State land-use control from 15A NCAC 2C should be placed on a Notice of Residual Contamination along with any additional local ordinances relating to a water line connection requirements, or well-installation or groundwater-use restrictions.

> *"Pursuant to 15A North Carolina Administrative Code 02C .0107 (b)(1), "(t)he source of water for any water supply well shall not be from a water bearing zone or aquifer that is contaminated"). Therefore, state law prohibits construction of a water supply well on this property. Further, pursuant to North Carolina General Statute 87-88(c) and 15A North Carolina Administrative Code 02C .0112(a), no*

well may be constructed or maintained in a manner whereby it could be a source or channel of contamination of the groundwater supply or any aquifer."

Table 5-1. Conditions requiring institutional controls.

Property	Condition	Land-Use Restriction (LUR) Document[3]	Notice of Residual Contamination (Survey Plat)[4]
CONTAMINATED SOURCE PROPERTY[1]	Contamination in **any medium or multiple media** above unrestricted-use levels	X	X
CONTAMINATED NON-SOURCE PROPERTY[2] – Multiple media	Contamination in **groundwater and other media** (e.g., soil, vapor) above unrestricted use poses multiple exposure risks (ingestion, dermal, inhalation)	X	X
CONTAMINATED NON-SOURCE PROPERTY – Groundwater only	Current or predicted contamination in **groundwater only** poses ingestion risk only (no vapor exposure risk)		X
UNCONTAMINATED NON-SOURCE PROPERTY in close proximity to neighboring groundwater contamination	A **threat of groundwater contamination** migration exists if pumping wells are installed on the property		X[5]

[1] Source property is where the site contamination originated.
[2] Non-source property is the property under separate ownership to which contamination has migrated.
[3] Land-use restriction documents require annual inspection and certification by the property owner.
[4] The Notice of Residual Contamination should have a "notes" section that states the condition of the property (e.g., current, predicted, or threat of groundwater contamination) and recites State or local land-use controls.
[5] The "notes" section should also state that "the non-source property is currently not affected by the identified source-property contamination, but based on the information collected to date, a threat of contamination may exist if water supply wells are installed on the non-source property."

5.3 General Principles for Restricting Land-Uses

Land-use restrictions are developed for each contaminated media according to the intended land use. Most will ultimately be negotiated with the landowner, but some are required by DEQ. In general, LURs typically follow the principles outlined below for each contaminated medium.

5.3.1 Restrictions for General Property Use

Each remedy that relies on LURs will need to consider the current and anticipated land uses from a risk perspective and tailor the restrictions accordingly. If a remedy involves cleaning up a site to non-residential use standards and restricting the property to such use, an evaluation of cleanup goals for construction workers and trespassers will also be necessary to ensure protection of those users.

Restricting a property to "industrial use only" is not equivalent to "non-residential use only." "Industrial use" in the zoning context generally allows for parks, recreational areas and day care facilities on industrial property. Similarly, "commercial use" can vary greatly from schools to activities similar to industrial use. If the intent of the proposed restriction is to prevent residential, day care, and school uses, the restriction should list the specific uses for which the property may not be used.

5.3.2 Requirements for Properties with Soil Contamination

Residential Use: Soil contamination exceeding direct contact remediation goals on residential property must be cleaned up to unrestricted-use standards unless an existing building overlies the contaminated material, it is technically impracticable to remove soils, or if the residential use will be mixed use with no residential areas on ground level. In these cases, LURs and proper engineering controls will be necessary.

Soil removal: Remedies not meeting unrestricted-use levels throughout the soil column, must include a restriction that bars taking soils off of the property.

Barriers: If the remedy utilizes barriers (caps) to prevent exposure to soil contamination that is present at concentrations that are higher than what is allowed for the intended property use, the barriers must be definable, visible barriers such as concrete, asphalt, or earthen material with marker fabric beneath and bollards, or fencing. A building foundation may serve as a barrier. The following general requirements may apply:

- The area covered by barriers should be generally rectangular in shape and not curved, irregular, or consist of multiple smaller patches of cover so the perimeter can be surveyed and the boundary depicted on the Notice/Survey Plat.

- A restriction should be included that does not allow disturbance of the barrier or disturbance of underlying soils (digging) without DEQ approval. There may be circumstances you can specify in the restrictive covenants where certain types of disturbance are allowed.

- As part of the annual certification, the owner must inspect barriers and certify they have been maintained in accordance with the specifications in the LUR document.

- Fencing with a vegetative cover over contaminated soils is an acceptable barrier if the area has no regular access and the risk assessment indicates the area is safe for a worker to maintain the vegetative cover and fence.

- *High vehicular traffic areas* must have durable barriers such as concrete or asphalt. Parking areas, and areas accessed by trucks and cars, are considered high-traffic areas.

- *Low or no vehicular traffic areas* can have an earthen barrier. If soil contamination is present within 10 feet of ground surface, a geotextile marker fabric must be used to warn of erosion. Typically, at least 1-ft of structural fill is placed over the contaminated soil and covered by the geotextile fabric, and then 6” of amended soil is placed on top to promote a vegetative cover. If contaminated soils are only present at depth greater than one foot, the geotextile fabric can be placed on an even land surface followed by 6 to 12 inches of soil fill for vegetative cover. The area perimeter must have a visible boundary such as bollards or fencing, or the whole property must be fenced.

- High-use areas, such as ball fields, kennel yards and horse riding rings will require earthen barriers of greater thickness (> 3 ft).

- If irrigation systems, lighting conduit or other infrastructure is desired within the earthen barrier, then the barrier must be of greater thickness, or must be built up, to accommodate the installation and/or maintenance of such systems.

- For earthen barriers, the owner’s annual certification report to DEQ must state that the depth and extent of the barrier has been measured and complies with the LURs.

5.3.3 Requirements for Properties with Groundwater Contamination

In general, where groundwater is remediated to site-specific, risk-based cleanup levels, a groundwater-use restriction will encompass the entire property. DEQ will require that the restricted area be marked by visible markers, such as fencing, or the property must be subdivided and restrictions placed accordingly. Use of existing and potential future groundwater pumping wells in the vicinity of a site must be considered in a risk evaluation to ensure that contaminant levels left in groundwater are protective of all current <u>and</u> future risks to human health and the environment. Remediators may need to request permission from property owners to restrict groundwater use where future water-supply wells could draw contaminants onto those properties.

5.3.4 Requirements for Properties with Vapor Intrusion Risks

When residual contamination poses a landfill gas risk or an indoor air risk to occupants of the property, engineered controls in the form of improved ventilation, a vapor barrier and/or mitigation system are required. Remediating parties will be expected to satisfactorily demonstrate through sampling or other direct means that the system is functioning as designed or that the barrier system is no longer needed. Requirements pertaining to the property owner’s routine inspection and maintenance of the controls will be included in the LUR document. The property owner will be required to certify annually that the control measures are operating as designed.

5.4 Recordation of Documents

The Survey Plat must be recorded first. The map book and page number of where it is recorded is then entered into the designated spaces on the LUR document. The LUR document is then immediately recorded.

To confirm proper recordation of documents, the remediating party must provide copies of the <u>recorded</u> documents with the following register of deeds notations: (1) the book and page number where the document was recorded and (2) the date of recordation. Confirm that the date of recordation noted on the grantor/grantee pages matches the date on the document. Also, your remediation program may require confirmation that the documents are referenced to the appropriate property on the grantor/grantee pages by either providing proof of a GIS search or request a certification of recordation. If this is not done properly, the recorded documents will probably not be found during a title search, meaning that subsequent owners may not be aware of the restrictive covenants in the LUR document.

5.5 Annual Certification of Land-Use Restrictions

All restrictions on property require annual inspection and certification by the property owner to ensure the remedy continues to be protective. If engineering controls are used to prevent exposure, restrictive covenants calling for the inspection and maintenance of the controls should be developed and specified in the LUR document and included in a section of the RAP. The inspection and maintenance plan must verify that the recorded LURs remain in place and activities at the site are in compliance with the restrictions. If only a Notice of Residual Contamination is being recorded on a property, no annual certification is required.

The property owner will be required to conduct, at a minimum, an annual inspection of the site. Owners must also annually certify compliance with LURs using a form provided by the appropriate remediation program indicating that the LURs are still in effect and that conditions at the site are not in violation of the LURs. The property owner must allow DEQ access to the property when requested and require the restrictions as part of future leases, grants and transfers. Current and future owners, and other responsible parties are required to enforce the LURs and are expected to take action immediately upon discovery of a violation of the LURs. Failure to do so will cause revocation of concurrence on the remedial action.

5.6 Cancellation of Land-Use Restrictions

If the owner believes that all hazards have been removed and that hazardous substances are no longer present at the site above unrestricted-use cleanup levels, the owner may request approval from the appropriate remediation program to cancel the LURs. Canceling LURs without prior DEQ approval will cause automatic revocation of approval of the RAP and will subject the party taking such action to enforcement.

6. REMEDIAL ACTION PLAN CONTENT

The RAP is a public document that should be written in a clear and concise manner in accordance with individual remediation program’s rules and guidance. It presents preliminary decisions and/or recommendations for a site that may require revision after public comments are received. If a RAP is already approved for a site, but a more cost-effective remedy is being considered, then a new RAP (or a RAP Addendum for minor changes) can be submitted. The new RAP/addendum should include the key elements outlined below.

In general, a RAP should reference the site assessment and remedial investigation report(s) on file, present the CSM, include a feasibility study of plausible remedial alternatives, present a detailed risk evaluation, describe the key components of the conceptual plan for site remediation and ensure the protection of public health, safety, and welfare and the environment. RAPs may or may not contain the specific engineering design details of the proposed remedial actions, but they must clearly set out specific remedial action objectives, including cleanup levels, and timeframes for completion of the remedial actions. For more complex remedies, the engineering design is provided in a pre-construction report or a remedial design plan.

The development of a RAP may require supplemental submissions and revisions based on Department review, remedial action pilot studies, and public comment from local government and citizens. The general contents of a RAP are outlined in detail in the Remedial Action Plan Contents document, but individual program requirements for a RAP may vary, so consult with your remediation program to confirm the information needed.

7. REMEDIAL ACTION COMPLETION and NO FURTHER ACTION

Once the RAP has been fully implemented and the objectives of the RAP have been met, a final report should be provided to the Department documenting that remedial cleanup levels have been met for the site and any other relevant information required by the remediation program.

Site closure, or NFA, is the termination of regulatory oversight activities related to a discharge. NFA status may be requested from the Department when information is provided to document that site remediation has achieved the approved cleanup levels or standards. All engineered controls planned for the site must be in place and all institutional control documents must be recorded with proof of such provided to the appropriate remediation program contact.

For sites using a risk-based remediation approach, a NFA decision means that the site is adequately remediated given the conditions in place at the time of the NFA decision. Risk-based remedies rely on institutional controls, and perhaps engineered controls, to ensure that the remedy is protective. Consequently, property owners must ensure that these controls are maintained and adhered to as described in the LUR instrument recorded for the site, and document such in the annual certification described in Section 6.

If DEQ determines that additional remedial action is necessary due to new information indicating the remedy is not protective, or due to a failure to adhere to required LURs, the Department may decide to rescind the NFA decision and require additional remediation.

Glossary of Risk Evaluation Terms

Attenuation Factor – The predicted ratio of indoor air concentration to subsurface vapor concentration, or the ratio of the predicted indoor air concentration to the concentration in groundwater established through a compilation of data from many sources.

Background - Three types of background levels may exist for chemical substances: (a) Naturally occurring levels: Ambient concentrations of substances present in the environment, without human influence; (b) Anthropogenic levels: area wide concentrations of contaminants such as dioxins, PAHs and PCBs not from a single source, but due to deposition from air; (c) Concentrations of substances present in the environment due to human-made, upgradient sources (e.g., automobiles, industries).

Bioaccumulative(tion) - The net accumulation of a chemical in or on an organism from all sources (food, direct contact with water, diet). The increase in concentration of a chemical in tissue compared to the environment, generally occurs with materials that are more soluble in lipids and organics (lipophilic) than in water (hydrophilic). Generally, a term limited for use to describe uptake by aquatic organisms.

Biomagnification – The accumulation of a chemical in or on an organism when the source of the chemical is primarily food and there is an increase in lipid-normalized concentration as the trophic level increases.

Capillary Fringe - The porous material just above the water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void spaces.

Carcinogen - An agent capable of inducing cancer.

Ceiling Concentration (Max) - The ceiling limit of 100,000 mg/kg is equivalent to a chemical representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may be violated (for example, soil adherence and wind-borne dispersion assumptions) due to the presence of the contaminant itself.

Chronic Exposure - Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species). Typically relates to the evaluation of non-cancer health effects.

Conceptual Site Model - A three-dimensional picture of site conditions that conveys what is known or suspected about the sources, releases and release mechanisms, contaminant fate and transport, exposure pathways, potential receptors, and risks. The conceptual site model is based on the information available at a given point in time and will evolve as more information becomes available.

Critical Effect - The first adverse effect, or its known precursor, that occurs to the most sensitive species as the dose rate or exposure concentration of an agent increases.

Exposure - Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

Exposure Pathway - The physical course a chemical or pollutant takes from the source to the organism exposed.

Exposure Point Concentration - The value that represents a conservative estimate of the chemical concentration available from a particular medium or route of exposure.

Exposure Route - The way a chemical or pollutant enters an organism after contact, e.g., by ingestion, dermal absorption and inhalation.

Exposure Scenario - A combination of facts, assumptions, and inferences that define a discrete situation where potential exposures may occur. These may include the source, the exposed population, the time frame of exposure, microenvironment(s), and activities. Scenarios are often created to aid exposure assessors in estimating exposure.

Hazard Index - The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, sub-chronic, and shorter-duration exposures.

Hazard Quotient - The ratio of estimated site-specific exposure to a single chemical from a site over a specified period to the estimated daily exposure level, at which no adverse non-cancer health effects are likely to occur.

Human Health Risk Assessment - The evaluation of scientific information on the hazardous properties of environmental agents (hazard characterization), the dose-response relationship (dose-response assessment), and the extent of human exposure to those agents (exposure assessment). The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree (risk characterization).

Institutional Controls - Non-engineering controls used to restrict land use or land access in order to protect people and the environment from exposure to hazardous substances remaining in the site/or facility.

Leachate - A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides or fertilizers. Leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, groundwater, or soil.

Non-Carcinogenic Effects - Effects other than cancer.

Particulate Emission Factor - This factor represents an estimate of the relationship between soil contaminant concentrations and the concentration of these contaminants in air as a consequence of particle suspension.

ppb - A unit of measure expressed as parts per billion. Equivalent to 1E-09.

ppm - A unit of measure expressed as parts per million. Equivalent to 1E-06.

Receptor – The species, population, community, habitat, etc. that may be exposed to contaminants. Receptors may be human or ecological.

Soil Saturation Limit (Csat) - The Csat is the contaminant concentration above which the contaminant may be present in free phase (NAPL or solid). Csat concentrations represent an upper limit to the applicability of the volatilization factor(VF) model used to generate soil screening levels for the inhalation route, because a basic principle of the model (Henry's law), does not apply when contaminants are present in free phase. VF-based inhalation PSRGs are reliable only if they are at or below Csat.

Sub-Chronic Exposure - Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately days in typically used laboratory animal species).

Target Organ - The biological organ(s) identified as the location of the most sensitive effect to a specific toxicant for a specific period of exposure to a chemical, physical, or biological agent.

Vapor Intrusion - The migration of volatile chemicals from contaminated groundwater or soil into an overlying building.

Volatilization Factor - An estimate of the rate at which a chemical is emitted from soil as a vapor.